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**First and second manuscript version for doctoral
dissertation**

(in Finnish: Ensimmäinen ja toinen käsikirjoitusversio
väitöskirjaa varten)

Preface

This publication contains the first version and the second version of manuscript for Lauri Lahti's doctoral dissertation:

Lahti, Lauri (2015). Computer-assisted learning based on cumulative vocabularies, conceptual networks and Wikipedia linkage. Doctoral dissertation of computer science, Department of Computer Science, Aalto University School of Science, Finland.

In Part I is shown the first manuscript version of the doctoral dissertation that was submitted for official evaluation on 21 January 2014.

In Part II is shown the second manuscript version of the doctoral dissertation that was submitted for official evaluation on 19 August 2014.

The third manuscript version of the doctoral dissertation was submitted for official evaluation on 21 January 2014 and a permission to publish was granted for the third version on 6 March 2015. The date of defence for the doctoral dissertation is 10 April 2015.

This publication aims to provide a historical perspective for the evolution of my research leading to the doctoral dissertation.

Helsinki, 9 March 2015

Lauri Lahti

PART I

**The first manuscript version of the doctoral dissertation
that was submitted for official evaluation on 21 January
2014**

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Computer-Assisted Learning Based on Cumulative Vocabularies, Conceptual Networks and Wikipedia Linkage

(in Finnish: Tietokoneavusteinen oppiminen perustuen
karttuviin sanastoihin, käsiteverkostoihin ja Wikipedian
linkitykseen)

Manuscript version 21 January 2014

Abstract

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Author:

Lauri Lahti (full name Lauri Esko Lahti, born 1975)

Name of manuscript:

Computer-Assisted Learning Based on Cumulative Vocabularies, Conceptual Networks and Wikipedia Linkage

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Field of research: Computer science

Abstract

We propose new methods and frameworks for computer-assisted learning. The work relies on eight peer-reviewed conference articles proposing new computational methods based on self designed and implemented software prototypes supplied with empirical user tests with them. Besides explaining results of the articles, we define terminology and background of the research, we combine theoretical and empirical analysis related to the research and we make concluding remarks summarizing the results of the research. First, we propose supporting different collaborator roles to address personal needs of each learner participating in collaboration and combining text-based parallel individual discussion chains that are illustrated cumulatively in a collaboratively agreed concept maps. Next, we propose a new method for guided generation of concept maps from open access online knowledge resources of the Wikipedia online encyclopedia (<http://www.wikipedia.org>). Then, we propose a new method for generating personalized learning paths from the Wikipedia by following inter-article hyperlink chains based on various rankings that are retrieved from the statistics of the articles. We extend the previous approach to manage simultaneous parallel ranking lists, diversely branching structures and different consecutive temporal versions of Wikipedia articles. Next, we propose a wiki representing pedagogical knowledge with a collaboratively edited collection of concept maps enabling to analyze maturing of knowledge according to various learner-driven criteria and to define pedagogically motivated learning paths and educational games. Then, we propose a new method to support the learner's knowledge adoption based on concept mapping relying on three perspectives of learner's knowledge, learning context and learning objective, each represented by a learning concept network, so that the learner explores ranking-based routings connecting learning concept networks based on the shortest hyperlink chains between corresponding Wikipedia articles. We propose a new framework relying on pedagogic conceptual network generated by linking the most essential concepts of a learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary enabling the learner to adopt vocabulary by

traversing links of pedagogic conceptual network in a sequential process having tailored variation and repetition computed based on theory of spaced learning and supplied with visualizations. We propose a new framework relying on cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic and alternating the distribution of enabled hyperlinks letting the learner to adopt knowledge by exploring hyperlink network and the shortest paths between concepts of vocabulary. We provide some estimates for the properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile database for cumulatively growing vocabularies corresponding to six language ability levels.

Keywords: intelligent tutoring, knowledge management, ontology, semantic web, concept map, language acquisition, wiki, learning model, small-world network, scale-free network, knowledge adoption, collaborative learning environment

List of publications and the contributions of the author

This manuscript is based on following eight publications [P1]-[P8] that have been published in peer-reviewed conference proceedings in years 2009–2013. In all of these publications Lauri Lahti has been the sole author and he has self designed and implemented software prototypes and carried out empirical user tests with them. Besides explaining results of publications, this manuscript offers introduction defining terminology and background of the research, supplementing theoretical and empirical analysis related to the research and finally concluding remarks summarizing the results of the research. The research of these publications has been carried out by Lauri Lahti at Aalto University School of Science (formerly Helsinki University of Technology until end of year 2009).

P1: Lahti, L. (2009a). Assistive tool for collaborative learning of conceptual structures. Proc. 13th Human Computer Interaction International 2009, Part III (Universal Access in Human-Computer Interaction – Applications and Services), 19–24 July 2009, San Diego, CA, USA (ed. Stephanidis, C.). LNCS 5616, Springer, 53–62. Print ISBN 978-3-642-02712-3 and Online ISBN 978-3-642-02713-0. http://link.springer.com/chapter/10.1007/978-3-642-02713-0_6

P2: Lahti, L. (2009b). Guided generation of pedagogical concept maps from the Wikipedia. Proc. World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education (E-Learn 2009). 26–30 October 2009, Vancouver, B.C., Canada (eds. Bastiaens, T. et al.). Association for the Advancement of Computing in Education (AACE), Chesapeake, Virginia, USA, 1741–1750. ISBN 1-880094-76-2. <http://www.editlib.org/p/32712>

P3: Lahti, L. (2010a). Personalized learning paths based on Wikipedia article statistics. Proc. 2nd International Conference on Computer Supported Education (CSEDU 2010), 7–10 April 2010, Valencia, Spain (eds. Cordeiro, J. et al.), Vol. 1, 110–120. SciTePress, Institute for Systems and Technologies of Information, Control and Communication (INSTICC). ISBN 978-989-674-023-8. <http://dx.doi.org/10.5220/0002800901100120>

P4: Lahti, L. (2010b). Educational tool based on topology and evolution of hyperlinks in the Wikipedia. Proc. 10th IEEE International Conference on Advanced Learning Technologies (ICALT 2010), 5–7 July 2010, Sousse, Tunisia (eds. Jemni, M. et al.), 233–235. ISBN 978-0-7695-4055-9 and ISBN 978-1-4244-7144-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5571281

P5: Lahti, L. (2011a). ConceptMapWiki – a collaborative framework for agglomerating pedagogical knowledge. Proc. 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), 6–8 July 2010, Athens, Georgia, USA (eds. Aedo, I. et al.), 163–165. Online ISBN 978-0-7695-4346-8 and Print ISBN 978-1-61284-209-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5992312

P6: Lahti, L. (2011b). Educational concept mapping method based on high-frequency words and Wikipedia linkage. Proc. 4th International Conference on Internet Technologies and Applications (ITA11), 6–9 September 2011, Wrexham, North Wales, UK (eds. Grout, V. et al.). Glyndwr University, Wrexham, Wales, UK. ISBN 978-0-946881-68-0. <http://www.ita11.org/papers.html>; <http://www.ita11.org/detailedProgramme.html>; <http://www.lulu.com/shop/vic-grout-and-stuart-cunningham-and-denise-oram-and-rich-picking/proceedings-of-the-fourth-international-conference-on-internet-technologies-and-applications-ita-11/ebook/product-17431522.html>

P7: Lahti, L. (2012). Educational framework for adoption of vocabulary based on Wikipedia linkage and spaced learning. Proc. Global Learn 2012: Global Conference on Learning and Technology, online conference on 6 November 2012 (eds. Bastiaens, T., & Marks, G.), pp. 8–13. Association for the Advancement of Computing in Education (AACE). ISBN 1-880094-99-1. <http://www.editlib.org/p/42033/>

P8: Lahti, L. (2013). Educational framework based on cumulative vocabularies, conceptual networks and Wikipedia linkage. Proc. London International Conference on Education (LICE 2013). 4–6 November 2013, London, UK.

A short characterization of each of these publications is provided in Appendix A and reprints of the original publications are in Appendixes AF-AM.

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Preface

I want to express my warmest thanks to everyone for helping me in the process of research that has produced this manuscript. I dedicate my work to all generations of learners and educators worldwide.

Place and date

Lauri Lahti

PART I. Providing guidance in network of educational knowledge

Chapter 1. Introduction

Constantly evolving society and cumulating amount of knowledge opens new possibilities for education. Understanding and adopting many theoretical principles and practical skills are important goals for every learner. Besides learning pieces of information and practices, learners should be provided with efficient learning skills that enable them to explore knowledge both independently and in collaboration addressing their personal educational needs.

Learning is a process and phenomenon that can be approached and analyzed from various perspectives. There are many competing and complementing *learning theories* that try to explain principles of learning and suggest recommendable activities for practical educational work. This manuscript proposes new methods and frameworks for computer-assisted learning that can be applied in various educational contexts for adoption and management of knowledge and can be combined with alternative supplementing learning activities and educational technology. The proposed new methods rely on interactive *software components* that aim to personalize collaboratively created knowledge structures to address needs of the learner. The development of new methods is motivated by previous research about properties of learning process and earlier promising results concerning intelligent tutoring systems and collectively built knowledge resources. Our research approach relies heavily on computer science and software systems and we present results based on eight peer-reviewed conference articles discussed in dedicated chapters and referenced to by notations [P1], [P2], [P3], [P4], [P5], [P6], [P7] and [P8]. The new methods have been implemented as software components programmed by the author as prototype tools. Various *user tests* have been carried out by the author with prototypes to verify suggested pedagogical gain of using new proposed computational methods. The benefits and challenges of the educational use of the methods have been analyzed. To position our research and to highlight many underlying multidisciplinary properties of learning that motivate development of our proposed computational methods and frameworks we provide a relatively broad synthesis about previous related research in Chapters 1-3 and Chapter 10.

1.1. Addressing the needs of the learners

To support human wellbeing in constantly developing modern societies finding new innovative educational working strategies has been considered important (Ainoa et al.

2009).¹ It has been internationally recognized that systematic coordinated efforts are needed to enhance development of educational systems. Funded by European Union, project Time for a New Paradigm in Education: Student Centered Learning (T4SCL) carried out in 2009–2010 by the European Students' Union and Education International (a global federation of teachers' trade unions) highlighted the need for resources to materialize a paradigm shift in educational practices (Attard et al. 2010). This paradigm shift should promote replacing conventional learning (or traditional learning) with student-centered learning.

Conventional learning typically considers students as passive receptors of information lectured by teacher whereas *student-centered learning* typically gives students the freedom and responsibility to form their own learning paths by active participation in educational process. Here *learning paths* can be seen as entities that describe a structure of actions a learner has to perform in order to attain a competence or a competence profile (Janssen et al. 2008). In fact, interest in favoring student-centered learning has obviously influenced that educational activities are nowadays often described from the learner's perspective rather than from the teacher's perspective. Furthermore, it seems that when talking about education, the concept of teaching—having historical connotations about relatively passive students—is sometimes replaced with the concept of learning to specifically emphasize the learner's role in adoption of knowledge.

Theories that try to explain learning process and try to help to develop advanced learning methods, possibly enhanced with technology, have often addressed the importance of taking into account how individual needs of the learner could be well addressed in learning activities. Research approaches considering the learner's individual needs has created varied theoretical frameworks dealing with so called *learning styles* which have proved to be very popularly applied by educators and offering significant area of consulting business claiming to be scientifically rooted. In a broad comparative analysis Coffield et al. (Coffield et al. 2004) pointed out the great challenge of trying to integrate diverse results about suggested learning style models and whether models relying on learning styles can really offer a promising theoretical approach for supporting learning. They argued that many educators have noted that traditional teaching methods based on transmission by teachers and assimilation by students are not working well with all students and thus there has naturally emerged a strong need among educators to try new techniques that are introduced and claimed to help reaching learning goals easier and addressing varied types of students.

¹ Despite of relatively long and vulnerable infant period *human species* have gained their exceptional survival in the evolution with their ability and eagerness to learn and to be creative. An important factor for survival and cultural development of the human species has been the altruistic human tendency of *sharing knowledge* with community members and *conveying knowledge* to future generations within folklore. This has been enhanced by establishing writing systems, libraries, printing and school system. The success of civilization largely relies on the rise of scientific worldview, cultural exchange, expeditions as well as foundation of university system with systematic organization of education and scientific work. To address principles of sustainable living it is important to see how life-long learning can be naturally incorporated to emerging and evolving future forms of working and education that prepares individuals to work.

Thus even if the actual validity of many learning style models remains yet to be verified there seems to be a strong motivation for developing and experimenting with educational theories relying on learning style models. Based on literature review, Pashler et al. (Pashler 2008) claimed that they did not find adequate evidence to justify incorporating assessments based on learning styles models in general educational practices and argued that it is important to identify teaching techniques that have experimental support and to abandon widely held beliefs if they appear to lack empirical support.

1.2. New methods to explore network of educational knowledge

A general goal in *computer-assisted learning* (also called as computer-supported learning) has been to support learning with *computational methods* that are typically based on some kind of automation.² Unfortunately, many earlier computational tools developed to support learning have suffered from lack of *personalization* (i.e. addressing learner's personal needs) and *updating* (i.e. changing provided learning content to keep it up to date). Thus despite of individual needs, a typical traditional computer-assisted learning system has provided to every learner relatively similar educational contents. This means that knowledge structures provided by the system and linking them to the previous knowledge structures already possessed by the learner has been permanently inflexibly determined when the system has been created. Some of the systems have enabled increasing and updating the knowledge structures of the system but it has often been possible only manually with a laborious process and resulted in each learning community to build redundantly their own educational contents without ability to combine more efficiently their efforts. These challenges have been typical especially with workstation-based, standalone and offline applications developed before and without the modern dynamic online connectivity and cloud based architectures, typically provided through Internet.

Anyway, it seems that best benefits from computer-assisted learning can be gained if technology is used as a complementing and supplementing resource for learning and thus computer technology should not be given dominating but instead supporting role. Based on multiround iterative survey done with preschool experts to identify key criteria for choosing Internet activities that enable developing cognitive, kinesthetic and affective competencies in a preschool child resulted in criteria that highlighted the need for interactive, developmentally appropriate activities that are not necessarily offered through Internet (Lombardi 2011).

Computer-based technology has been seen as a promising solution to offer new kind of support tools for independent personalized learning that is free from many time and location constraints. In educational technology typical challenges have been dealing

² A general motivation for evolution of *computer science* has been an aim to provide automation for processing information through methods of computing and organizing data but still today many early expectations of developing truly intellectual human-like – or even superior – computers have remained largely unattainable.

about how to implement *interactive adaptive visualization* about a desired educational content to address the learner's current personal needs. Here it should be noted, that term visualization is used in this context to cover besides visual illustration (i.e. illustration perceived through eyes) also *non-visual forms of illustration* such as auditory (i.e. hearing-based) and tactile (i.e. touching-based) sensory communication.

In this dissertation we introduce a set of computational methods that we have developed to support learning. We have combined these methods into a collection of *software modules* that can be used together to various educational purposes, especially for exploration of online resources but also for offline-use if needed. The methods can also be used as separate individual components that can be added as plug-ins to other implementations of educational software. This requires that those other software units support data communication with the components through their interfaces. Our research tries to find answers to persistent challenge of generating *guidance* for personalized exploration in knowledge structures and supporting *agglomerating* and *linking* pieces of knowledge in a pedagogically fruitful way.

Our proposals are inspired by adaptive and efficient link structures that have properties of so called *small-world networks* and *scale-free networks* and even both of them together. Small-world topology emerge in a diversity of natural processes: both structurally and functionally in human brain networks (Wang et al. 2010), social networks (Uzzi et al. 2007) as well as in wikis that are collaboratively edited web sites (Mehler 2006). Bullmore and Sporns (Bullmore & Sporns 2009) mention that some studies indicate scale-free properties in functional brain networks ((Eguíluz et al. 2005); (Van den Heuvel 2008)) and some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)). Our work largely relies on exploiting knowledge structures of the *Wikipedia online encyclopedia* (<http://www.wikipedia.org>), the currently largest wiki and online encyclopedia freely available and holding properties of small-world network (Ingawale et al. 2009) and furthermore properties of scale-free small-world network ((Zesch & Gurevych 2007); (Masucci et al. 2011)).

The set of methods and frameworks introduced in this dissertation aims to support learning with the following complementing emphasis:

- identifying and addressing distinctive roles of collaboration typical for each personal individual participating in complementing collaborative learning process that can produce cumulatively a mutually agreed knowledge structure with intuitive visualization
- exploiting the knowledge structure of the Wikipedia online encyclopedia to provide guidance for promising educational exploration in new knowledge for the learner
- generating adaptive visualization with concept maps about the exploration in the Wikipedia along promising learning paths
- using statistical features concerning the Wikipedia articles to suggest promising different learning paths for exploration emphasizing different characteristics in the educational domain
- letting the learner to get simultaneously parallel alternative recommendations for exploration enabling her to build diversely branching knowledge structures according to her needs
- using the consecutive temporal versions of Wikipedia articles' edit history to suggest promising learning paths showing evolution of conceptual structures
- building a wiki-based cumulative repository of concept maps that can be used collectively for various educational purposes with learner-driven criteria
- using knowledge structure of the Wikipedia to generate promising learning paths to link new entities of educational knowledge to the learner's prior knowledge, supported with augmenting collective and everyday knowledge
- generating learning paths in conceptual networks adapted from hyperlink network of the Wikipedia in a sequential process having tailored variation and repetition computed based on theory of spaced learning and reaching vocabulary sizes suggested to suffice for reasonable comprehension in human communication with cumulative vocabularies tailored for consecutive levels of language ability

In this dissertation chapter by chapter we explain underlying motivation for the methods we have developed and the way their implementation has been carried out with a software systems approach. With experimental results gathered in real educational setting with groups of learners we aim to give convincing verification for suggested pedagogical gain of using the methods.³ Based on our research described in publications [P1]-[P8] we cumulative build a complementing collection of methods that can be used in two general educational frameworks that we propose in publications [P7] and [P8] and discuss in Chapter 11. This cumulative modular structure of our research and this dissertation aims to synthesize our findings and hopefully can offer inspiration for future research and application of gathered insight in practical everyday educational work in any forms of life-long learning both individually and collaboratively.

³ To promote open distribution, the *methods and software components* supporting learning that we have developed and implemented in our research described in publications [P1]-[P8] are meant to be public so that details of used research methodology, computational models, program code and data structures are available from the author by request.

1.3. Research questions and research methodology

Our research relies on developing educational methods that are inspired by the collaboratively maintained knowledge structure of the Wikipedia online encyclopedia and representing, exploiting and mimicking its features and content. Due to the Wikipedia's many unique characteristics (including its popularity, coverage and constant updates) we consider the Wikipedia to offer much more than just a quick encyclopedic reference for factual information. Instead, we think that the Wikipedia can provide an promising example, model and analogue for *construction of human knowledge* that can be applied in varied scales and context of life. Especially we find it fascinating to suggest that the processes that can be identified and modeled in the building and accessing the Wikipedia can provide a promising example, model and analogue for thinking in an individual human mind and how learning process can happen through adoption, chaining and agglomeration of pieces of knowledge with a kind of network structure.

In the current era of networking and popularity of social media, *participatory design* has appeared as a promising way to collaboratively build resources by volunteers to serve themselves and encountered needs. A closely related variation is *crowdsourcing* that refers especially to commercial exploitation of ordinary people by engaging them to activities that essentially help to model and track customer activity patterns and to build brand visibility in the media through embedded or viral marketing. Some of the traditional challenges that emerge in ordinary efforts to motivate people to work individually and collaboratively can be also present with participatory design and crowdsourcing but they can be often overcome with suitable rewarding schemes or even indeed due to the absence of rewards that gives a specific honorary status for the voluntary work.

Our research aims to exploit the knowledge structures built in wiki style that form the Wikipedia. We decided to exploit especially the Wikipedia since apart from many other collaborative online projects it seems to have been exceptionally successful in maintaining high popularity in general reading access—and what is even more delighting—maintaining high volunteer activity in writing, editing and other maintenance work as well. Thus the Wikipedia has addressed a crucial requirement: how in the first place to get people involved to contribute and then later, indeed, to keep them constantly updating by reviewing and further editing. It seems that the fundamental principles of free access and editing has enabled the Wikipedia to avoid challenges that purely commercial corporations face when trying to convince people to spend time voluntarily with their proprietary products.⁴

To address various challenges concerning supporting learning with adaptive collaborative knowledge resources and recommendation systems based on them, we

⁴ We think that it might be the Wikipedia's very humane and noble goal of offering a free extensive knowledge resource for everyone that has made volunteers devoted to contribute to its building so willingly. It has been also suggested that there is a pretty active specific segment in general public who might find themselves especially attracted to *process writing* that offers some sort of publicity and fame and who form a core community of contributors of the Wikipedia.

discuss in this dissertation possible promising solutions that take inspiration from the following *main research question*:

What kind of methods are promising for developing computer-assisted collaborative knowledge management systems that aim to support cumulative exploration and adoption of new knowledge addressing the learner's personal needs in various contexts and collaborative processes and that can exploit knowledge resources of Wikipedia online encyclopedia?

This main research question covers a large range of issues concerning computer-assisted learning as well as theory and practice of educational work. Therefore we have decided to divide the main research question into several subquestions that we expect to be possibly easier to address efficiently. Our research has specific emphasis on *computer science and engineering* and developing *software systems* that can be applied to address educational needs in various learning scenarios. Thus we recognize that our research can not exploit and combine all possible methodology introduced in other research fields that are related and affiliated to learning and education. Methods and models developed in our research are strongly motivated and inspired by findings in other fields of research, including for example mathematics, psychology, neurology, cognitive science, pedagogy, sociology and organizational management, but our inherently strongest field of expertise and contribution is positioned in the field of computer science and its applications to education.

Main themes of our research are further explained in Appendix B by formulating a list of questions that divide the main research question into more manageable units (see Appendix B). To find some answers to the main research question we needed to select a suitable *research methodology* that takes into account the current research field with its traditions and the context in which our research was going to be applied. Since this dissertation is carried out in the field of computer science with some influence from fields of software systems and educational technology, our chosen methodology emphasizes development of new *computational models* and their implementations as functional *prototype software modules* that are applied in real social user environment. We have done our best to take sufficiently into account diverse prerequisites and requirements that belong to complementing multidisciplinary fields of our research.

Engineering research is strongly guided by *empirical and experimental work*. However, since computational models have a *mathematical and analytical motivation* there is also a strong aim to make theoretical and logical contribution in research of computer science. Our current research has tried to balance fruitfully between theoretical and practical aspects of engineering research. We aim to develop computational models that can support learning and to reach this goal it is important to try to bring theoretical results sufficiently applied to practical life immediately or at least in the very near future.

The computational models we propose for offering *recommendations* to the learner about promising learning paths are somewhat constantly evolving models and can be considered to contain some kind of learning properties typically belonging to *artificial*

intelligence.⁵ Furthermore, it needs to be noted that computer science literature refers often to concept of “*learning models*” meaning typically generation of predictive *probabilistic models* based on input data available from an observed phenomena that can belong to almost any field of life. However, in our research as well as in general terminology of pedagogy and educational technology, concept of “learning models” means typically *tailored schemas* identified to successfully represent recommendable human learning processes, often emphasizing certain perspectives and activities considered especially useful for the learner’s education.

In this dissertation we use rich synonymous terminology when referring to educational technology and computer-assisted learning in general. If we have not identified a reason to differentiate specific meanings, we use relatively liberally concepts of computer-assisted learning, computer-supported learning, e-learning and resembling expressions with the approximately same meaning.

Since our research focuses on modeling operational principles in complex human-based collective cognitive activities we have tried to incorporate to our engineering oriented research also *multidisciplinary influence* from other related research fields. To keep our research in a compact and manageable form, we have been forced to make hard decisions about research methodology and perspectives that can be included and covered in this dissertation.⁶ We hope that our current research can serve as an inspiration for future research and encourage others to continue the work despite the evident challenges and incompleteness inherent in this research field.

1.4. Modeling knowledge adoption

In respect to diverse and competing spectrum of educational theories, we have decided to consider in our work the learning process in the light of few popular and respected interpretations of *learning theories*. Learning theories try to scientifically explain what actually happens in learning. Like theories in general, also learning theories are in constant evolution and it seems that various trends emerge and disappear and old ideas become recycled after some time has passed.

Baggio (Baggio 2009) claims that four learning theories are relevant when considering creation of cognitively supportive multimedia learning environments and these four are behaviorism, cognitivism, constructivism and humanism. Descriptions

⁵ Due to common terminological confusion in computer science, it needs to be clarified that our research about “learning” primarily refers to learning in the context of education. When talking in this thesis about learning we typically mean a *human learning process*. Thus learning dealing with so called “learning algorithms” in the context of *artificial intelligence* that typically aims to mimic neural processes for example to train models of pattern recognition for computer vision are not primary subjects of our research. However, we think that our proposed models hold some such characteristics that they can actually be considered to enable some kind of *autonomous learning on the algorithmic level* of our models. For example, our research relies on assumption that typical learning activities proceed cumulatively in a process of chaining essential pieces of knowledge in fruitful ordering in respect to the learner’s personal needs.

⁶ We recognize that our research can represent only a fraction of the issues concerning computer-assisted learning but we hope that our work can fruitfully complement previous work by helping to increase understanding about the processes involved in learning and how learning could be supported with computational methods.

given by Baggio mention that *behaviorism* observes learning to emerge as a change in observable behavior resulting from experiences, *cognitivism* observes learning to emerge when learner processes gained information to build a mental representation of it, *constructivism* observes learning to emerge when the learner actively discovers knowledge in interaction with the world and *humanism* observes learning to emerge through a learner's desire to reach fulfilled human qualities thus enabling to making positive decisions.

Taking into account ontological and epistemological assumptions, units of analysis and the mind-body relation, Schuh and Barab (Schuh & Barab 2008) have proposed a classification that consists of five major psychological perspectives providing a foundation for learning and instructional theories: behaviorism, cognitivism, cognitive constructivism, sociocultural/historicism and situative theory. In brief, *behaviorism* has been seen to focus on objectively observable behaviour of learning, *cognitivism* to focus on inner mechanisms of human knowing and thinking, and *cognitive constructivism* to focus on a process approach in which the learner actively constructs ideas and concepts, *sociocultural/historicism* to focus on interaction between individuals in a society, and *situativity theory* to focus on situations in which individual act.

Schuh and Barab (Schuh and Barab 2008) name one influential learning theory for each of these perspectives: behaviorism is influenced by Skinner's operant conditioning (Skinner 1938), cognitivism by Ausubel's meaningful reception learning (Ausubel 1977), cognitive constructivism by Piaget's scheme theory (Piaget 1952/1936), sociocultural/historicism by Vygotsky's zone of proximal development (Vygotsky 1978) and situativity theory by Lave's and Wenger's legitimate peripheral participant (Lave & Wenger 1991). Furthermore, Schuh and Barab (Schuh & Barab 2008) give one example of instruction theory or method for each of these five psychological perspectives: behaviorism is expressed in programmed and computer-aided instruction, cognitivism in Gagné's conditions of learning (Gagné 1985), cognitive constructivism in discovery learning, sociocultural/historicism in reciprocal teaching or scaffolding and situative theory in anchored instruction.

Our research relies on an assumption that computer-assisted learning should try to fruitfully take influence from all of these five major categories listed by Schuh and Barab (Schuh & Barab 2008), and probably even from further complementing categories since each categorization alone typically have their own constraints. Thus we think that adaptive learning tools should for example exploit monitoring the learner's activities, let the learner to follow her intuition, support the learner to build constellations about her conceptualization, enable fertile collaboration in a learning community and make the learner engaged in solving realistic problems.

In a meta-analysis covering 658 studies on game-based learning, Wu et al. (Wu et al. 2012) found out that only 91 studies were based on one of four learning theories they aimed to identify so that 48 studies were considered to be based on constructivism, 25 based on humanism, 17 based on cognitivism and 15 based on behaviorism, and among representatives of behaviorism 9 relied on direct instruction, 3 programmed instruction and 3 social learning theory.

Cognitive science refers to interdisciplinary research studying mind as an information processing entity and being influenced by many related traditional academic research fields. An important aim in this research domain is to develop models capable of explaining consciousness (Blanquet 2011). Our work takes inspiration from cognitive models concerning *social cognition* which deals with questions about how mental processes and learning can be influenced by collaborating with surrounding social group ((Bargh 2006); (Frith & Singer 2008)). Early work concerning how group processes affect mind has been identified in a cognitive model based on *schemata* that enable relating new experiences against the background of earlier experiences at the intersection between organism and its environment (Wagoner 2013). Processes of social cognition have been also approached with *attribution theory* suggesting how people explain causes behind different behaviour and events (Oghojafor et al. 2012). *Bayesian theory* extends traditional logical reasoning to evaluating probabilities of the truth of the hypothesis that can be sequentially (iteratively) updated with new relevant data (Gill 2007). The formulation of Bayesian probabilities can be seen to be based on either *subjective belief* of or on the *objective state* of the knowledge. Complexity of many Bayesian methods can be managed computationally with approximations based on *Markov model*, including *Markov chain* for cases with fully observational system states and *hidden Markov models* for partially observable system states.

To ensure good usability for *user interfaces* of systems so that they can help the users to reach their goals based on their intentions Li (Li 1999) suggests that the design of user interfaces should enable both an easy way of action and a natural way of action with specific design criteria. To address the easy way of action, the design criteria should include easy perception and less attention (proper amount of information with 5–9 chunks, easy detectability and recognizability, visualization of artifacts, desired affordance, visual guidance, and economy of perceptual processing), easy cognition and less effort (to make the behavior of artifacts visible, to find consistent mapping of human action on computer operation, to offer understandable and rememberable meaning of information, to employ everyday logic and heuristic way of problem-solving, and to make memory easily), easy physical performance (direct perception, perceptual-motor coordination and easy learning) and action guidance (concerning intention, reparation, plan, implementation and termination). To address natural way of action the design criteria should include natural context, language and information, natural ways of perception and attention (coordinated coupling of information, perceptual desires and modalities), natural ways of cognition (multiple relations between desired mental processes and information, immersion and learning) and natural ways of physical performance (natural input and interaction devices and offering natural environment).

Our research tries to develop computational methods to assist learning and managing conceptual knowledge structures. Theories about concept learning are diverse and disagree about many fundamental features of learning process. *Concept learning* is a process that deals with learning conceptual categorization that is often also referred to as concept attainment and concept formation. One of the early works promoting

categorization as an important aspect of cognitive processes explores the factors concerning how in thinking involves grouping of things (Bruner et al. 1956). Concept learning has been explained with various competing theoretical frameworks, including for example rule-based theories, prototype theories, exemplar theories and Bayesian theories (Goodman et al. 2008).

Perceptual categorization has been often explained with *single-system models* assuming that categorization is based on existence of a unique representation (Ashby & Gott 1988) and one popular type of single-models are *exemplar models* which assume that category exemplars are stored in a person's memory classifying new stimuli according to their relative similarities to the stored exemplars (Medin & Schaffer 1978). An alternative explanation for perceptual categorization has been *multi-system models* assuming an interaction between two distinct category representations relying on explicit representation based on simple rules and implicit representation based on exemplars or more complex rules (Ashby et al. 1998). *Prototype theory* assumes that categorization relies on idealized prototypical representations defining critical features of category and sufficient matching is used for classification of new stimuli (Rosch 1973). In categorization of concepts it has been suggested that *similarity between two representations of stimuli* can be determined based on their distance in underlying psychological space and that the value of similarity possibly decays according to function e^{-cd} (Shepard 1987) where d is distance between representations and c is an assistive parameter, or according to similar function with d raised to power of 2 (Nosofsky 1986).

Research has identified neural activities correlating with some of the suggested psychological models about categorization, for example in *functional magnetic resonance imaging* it has been observed activation of medial temporal lobe that is consistent with two predicted psychological processes enabling exception learning which are item recognition and error correction (Davis et al. 2011). In perceptual categorization task new stimulus dimensions can emerge when attention given to already existing dimensions do not help in separating stimuli from different categories and there is a simple linear combination of the existing stimulus dimensions so that stimuli belonging to opposite categories can appear at different ends of this emerging dimension. (Rodrigues 2008)

When trying to classify large collections of knowledge leads often to the *curse of dimensionality*, i.e. as the number of dimensions of data rises the contribution coming from single dimension decreases leading to fuzziness of the concept of the nearest neighbour. Network-based methods have been suggested for solving this challenge by converting high-dimensional data to low-dimensional codes (Hinton & Salakhutdinov 2006). We think that *neuroimaging* technology will likely in the near future offer a great resource for modeling processes of learning and thinking in general. For example, there have already been efforts to introduce low-cost electroencephalography for task classification in human computer interface (Lee & Tan 2006). Furthermore, it has been found recently possible with functional magnetic resonance to decode and reconstruct people's dynamic visual experiences relatively successfully (Nishimoto et al. 2011).

However, while waiting that the level of neuroimaging research results reach a sufficiently extensive, accurate and reliable solutions for modeling learning, we think that it is now still important to invest also in research relying on more traditional approaches and that is what we are doing. Therefore we see that we are currently living in a *transitional period* in the history of technological advancement and its applied research concerning learning. It is a responsibility for current generations to invest on very detailed biology based research approach that typically progresses slowly and can be expected to help profoundly only future generations in respect to understanding very well the human mental processes. However we think that there is also a strong need for more abstract and thus more rapid even if *robust research approach* relying on more conceptual abstractions of logic and psychology to develop methods that can quickly help current generations in understanding at least a little bit better than earlier the mental processes. Our research reported in this dissertation follows especially the latter approach thinking that with very good luck even this more robust approach can open some revolutionary scientific breakthroughs on a fast-track even if the risks of making a misinvestment of research resources might be much higher than with the former approach.

1.5. Main contributions and structure of this dissertation

We summarize here the main contributions of our current research work and at the same time describe the contents of the different parts of this dissertation:

Part I. Introduction and background

We introduce motivation for the dissertation and some issues related to background of the current research. The Chapter 1 gives a short introduction. The Chapter 2 discusses about the needs for computer-assisted education and Chapter 3 about collaborative educational processes in networks.

Part II. Collaborative building of link based knowledge representations in learning

Chapter 4 summarizes Publication [P1] in which we introduce a computational framework to support collaborative knowledge building process and suggest computational methods to exploit cumulatively the complementing individual resources in learning to reach mutually agreed results combining text based discussion and concept mapping. Chapter 5 summarizes Publication [P2] in which we introduce a computational method to assist exploration of collaboratively built hyperlink structure of the Wikipedia online encyclopedia represented with concept maps to gain pedagogically rewarding exploration.

Part III. Generation of alternative personalized learning paths in link based knowledge structures by using statistical and historical data

Chapter 6 summarizes Publication [P3] in which we introduce computational methods to generate alternative learning paths in the hyperlink structure of the Wikipedia relying on statistical features of articles and represented with concept mapping. Chapter 7 summarizes Publication [P4] in which we extend the computational methods introduced in publication [P3] to support that the learner can simultaneously operate with parallel ranking lists of hyperlinks, the concept map construction emphasizes building diversely

branching structures, and different consecutive temporal versions of Wikipedia articles can be browsed.

Part IV. Connecting and agglomerating entities of collaborative knowledge resources based on personal contributions

Chapter 8 summarizes Publication [P5] in which we introduce a computational framework to support collaborative knowledge building process relying on a wiki based methodology with concept mapping supporting use of various educational games to explore and edit knowledge structures. Chapter 9 summarizes Publication [P6] in which we introduce computational methods to help the learner's knowledge adoption with concept mapping relying on concepts of three perspectives of learner's knowledge, learning context, and learning objective that are connected based on hyperlink network of corresponding Wikipedia articles.

Part V. Forming new educational activities based on vocabularies, conceptual networks, and spaced learning

In Chapter 10, with an aim to better relate methods proposed in publication [P1]-[P6] to fundamental characteristics emerging in any typical learning situation, we introduce a brief review about some fundamental characteristics that have been identified in previous research concerning human learning process and representation of knowledge and that according to us can be seen to offer both useful potential and challenging constraints for development of new educational activities based on conceptual networks especially in respect to computer-assisted education. In Chapter 11, considering the review of fundamental characteristics affecting knowledge adoption just presented in Chapter 10, we suggest a combination of two new frameworks that we have synthesized based on methods we proposed in publications [P1]-[P6] and these two new frameworks were proposed in publications [P7]-[P8]. Chapter 12 offers discussion covering. In Chapter 12 some central themes of our research introduced in publications [P1]-[P8] and covered in previous parts of this dissertation are discussed and some recommendations for future work are provided.

Part VI. Additional resources

Contains a list of references and appendixes which include also reprints of the original publications [P1]-[P8].

To illustrate the evolution of our research and how eight individual research articles contribute to a greater entity of research results, the Table 1.1 characterizes some essential components and their relationships in our work.

In our research we have defined general methods and perspectives to identify fruitful pedagogical ways to support learning and creativity. These efforts have maintained on rather abstract level aiming to categorize and conceptualize components and processes of learning. On the other hand, we have designed and developed practical tools to support learning. We have built new computational methods and frameworks based on previous models and research results found in literature as well as based on our own innovation and experimentally gained modeling. Since our work primarily represents research of computer science and especially with some influence from fields of software systems and educational technology, we developed new methods and tools by designing

and programming suitable data structures, user interfaces, web connectivity and operational logic.⁷

⁷ We have tried to maintain good options and possibilities for later updates, modifications and augmentation when designing and implementing our models and tools. We believe that prototyping, open-source movement and modularly distributed solutions are currently promising approaches to be used in software development work. Even if there are still supporters of more traditional philosophy of developing software we believe in relatively agile, improvised and collectively *gradually fine-tuned* development strategy. It seems for us more useful to launch software solutions in beta-testing phase so that the user community and research community can contribute in giving feedback in early phase and at the same time already also benefit of the use of the tools to increase quality of life.

Table 1.1. Evolution of the research carried out for this dissertation in respect to eight individual research articles showing some of their essential components and relationships.

1. Collaborative learning framework (publication [P1])

- 1a. collaboration to find agreement
- 1b. illustration with concept map
- 1c. tracking activities of learners
- 1d. guidance for personal roles and needs

2. Exploiting knowledge of the Wikipedia (publication [P2])

- 2a. relying on collective ontology for learning
- 2b. exploring hyperlink network
- 2c. personally traversed learning path (augments 1d)
- 2d. visualization of learning path as concept map (augments 1b)

3. Statistical guiding in learning path network (publication [P3])

- 3a. identifying various perspectives in respect to article statistics
- 3b. alternative rankings for traversable paths (augments 2b)
- 3c. selecting suitable perspective for traversals
- 3d. chaining knowledge in different perspectives (augments 2c)

4. Building branching learning path network (publication [P4])

- 4a. branching parallel learning paths (augments 3a)
- 4b. cross-linking knowledge of various complementing perspectives (augments 3d)
- 4c. exploring the latest version or temporal evolution of hyperlink network
- 4d. addressing cumulatively encountered knowledge and emphasis on definitions

5. Building collective learning path network as a wiki (publication [P5])

- 5a. identifying overlapping complementing learning path segments (augments 4b)
- 5b. defining recommendable learning paths (augments 1a)
- 5c. collective creation and evaluation of knowledge entities for learning
- 5d. enabling learning path networks for educational gaming

6. Agglomerating pieces of knowledge (publication [P6])

- 6a. diverse personal entities of knowledge
- 6b. connecting own knowledge to respected core knowledge (augments 3d)
- 6c. traversing shortest paths in focused and contextual knowledge (augments 2a)
- 6d. defining forms of basic learning games (augments 5d)

7. Spaced learning of cumulative vocabularies (publication [P7])

- 7a. generating learning paths in a sequential process
- 7b. tailored variation and repetition based on spaced learning (augments 6b)
- 7c. reaching vocabulary sizes sufficient for human communication (augments 5b)
- 7d. cumulative vocabularies tailored for consecutive levels of language ability (augments 4c)

8. Cumulative exploration in conceptual network relying on growing vocabularies based on language ability levels (publication [P8])

- 8a. identifying language ability levels for progressive stages of learning (augments 5a)
- 8b. generating cumulatively expanding hyperlink network connecting concepts of vocabulary (augments 2b)
- 8c. exploration of shortest paths between concepts having highest rankings and strongly rising rankings (augments 6c)
- 8d. guiding adoption of knowledge with cumulative conceptual networks with principles of spaced learning (augments 7d)

Chapter 2. Needs for computer-assisted education

This chapter introduces current and emerging trends for the needs identified for developing computer-assisted education. There exists various parallel research fields and school of thoughts aiming to comprehend and model learning activities and support them with computational methods. We understand that the perspectives taken in our research are always to some extent subjective and deserve to be taken into critical consideration by the reader. However, we have tried to carry out our research in a systematic way with actions that are transparent and traceable by others. We aim to introduce our research in steps that enable the reader to achieve logical understanding of continuity ranging from ideas and formulation of models to implemented software prototypes and evaluation of experiments carried out with them.

2.1. New challenges for supporting education

Our research originates from the author's and the research community's notions that there is a need to develop adaptive computational methods that can support learning in respect to modern scientific theories about how to fruitfully support learning and exploiting new technological resources that have become available in everyday life. For example some suggestions have been created for a framework for research on technology-enhanced special education (Jormanainen et al. 2007).

To offer computational methods to support practical learning efforts of a learner several aspects need to be taken into account. We have listed here some relatively general aspects that we have considered important when designing computational methods to support learning:

- how the learner can be guided by the method following her educational needs
- how to address variety of different learning styles (or preferences) among learners
- how to address variety of prior knowledge of learners
- how to implement an intuitive user interface
- how to implement adaptive methods responding to the learner's actions
- how to keep the system that supports learning updated and popular
- how to efficiently create, store and represent knowledge needed in educational processes
- what kind of structure and processes are optimal for linking and agglomerating the pieces of knowledge in a greater entity
- how adoption of knowledge could benefit from tailored spacing and cumulative vocabularies
- how collaboration of learners and/or educators can be used for benefit in learning and how that can be supported
- how the performance and progress in learning can be measured and evaluated

- how the learning of the learners and research of educational technology can fruitfully support one and other

To develop some solutions that address these issues we considered important to position our ideas in respect to previous work carried out in the research fields related to education and computer science. For the development of *educational possibilities* of the whole humanity, it has been a very positive progress that along centuries and decades humans have systematically collected verified knowledge, documented it and started to distribute and exchange it in hand-writing, in print, by radio and television broadcasting and finally through multimedia-supported computer networks including the Internet. Public school systems have been established to provide centralized and qualified learning environments with professional teachers and making children exposed to broader spectrum of complementing facts and opinions than they could get solely at home.⁸

When making review about previous research and existing methodology and technology we witnessed a large variety of *different perspectives*, claims and beliefs that are applied in practical educational work. There is a large variety of *different schools of thought*. It has remained hard to verify many of claims about recommendable practices for learning and even many of the most principal questions about learning remain open. For example, historical, cultural and religious opinions have largely affected the way children in different time and in varying locations have been taught.

Since the current youth generations have already inherently adopted new *behavioural language and grammar* to live with modern technology and they have populated the Internet as one of their playgrounds it is important to establish educational services that support using also these new resources and technical skills.⁹ No one can yet surely say if learning with certain technological devices and Internet-based services can necessarily provide better *overall learning experience* than for example a traditional classroom but at least it is still too early to condemn emerging applications of educational technology. In fact it seems that educational technology can serve at least as a fertile supplement to other methods of learning thus positively enhancing learning results.

⁸ Skills of *critical thinking* and *freedom of thinking and speech* are essential for balanced evolution of civilized societies and these principles should be strongly encouraged among all school children and students. Progress of a society is strongly dependant on well-organized education that is offered to all of its growing citizens. Like previous generations have unselfishly developed and enhanced the chances for learning for current generations with the resources then possible, it is now our responsibility to continue the progress further by actively exploiting newly opened modern resources that have not been earlier available. Since scientific and technological innovations constantly change our everyday life and worldview it is important to develop learning into such direction that best addresses the new requirements and possibilities of the current time.

⁹ School children and students of today have born and lived in a very different world than any earlier generations, and even very different than in their parent's youth 20-40 years earlier. On technological side, the mobile phones and Internet have revolutionized the way people can follow news, communicate in real-time, get entertained, do shopping and access various other online services. Wide-spread use of computers, embedded systems and smart phones in all areas of everyday life with a huge *variety of functional logic* and user interfaces ranging from mp3 players to social media applications have introduced to current youth generations a new form of *behavioural language and grammar* about how to express oneself, how to communicate, how to search information and how to use purposefully a diversity of technical devices through their user interfaces.

2.2. New organization for educational activities

A great traditional challenge in education has been strong reliance on *classroom teaching* organized by a teacher following her personal devotion, commitment and agenda. Despite of planning work in advance, the teachers often face in the actual classroom setting a need to improvise due to many unexpected situations. Thus organization of educational content, methods to represent them and personal guidance of learners and allocation of resources are often carried out somewhat spontaneously by the teacher. Largely due to *cost-effectiveness* a group of learners has been typically taught by only one teacher at time. We think that there is a strong need for *computational methods* that can augment and broaden the traditional way to organize learning so that the learners could more independently carry out learning tasks and at the same time be supplied with useful automated personalized pedagogical guidance.

Like in many other fields of research, also in educational field many ideas suggested for development regularly face a renaissance, become reinvented or remain on hold since practical implementation appears challenging. We think that an influential early pedagogical framework that still maintains important value for development of new educational activities, giving valuable inspiration for our research as well, is Vygotsky's proposal of *proximal development* that relies on idea that with suitable aid from an educator a learner can gradually extend abilities beyond her unaided abilities (Vygotsky 1978).

Since a teacher can typically give specifically *tailored guidance* only to one learner at time we think that automated support systems can enhance effective learning by helping the learner to avoid unnecessary moments of confusion and waiting.

Kuhlthau (Kuhlthau 1994) suggests that information search process can be represented with five *zones of intervention* addressing gradual levels of complexity so that each intervention zone is associated with specific level of mediation and education: self service (no direct intervention) is provided by organizer-type education with organizer-type mediation, single source intervention is provided by lecturer-type education with locator-type mediation, group of sources intervention is provided by instructor-type education with identifier-type mediation, sequence of sources intervention is provided by tutor-type education with advisor-type mediation, and process intervention is provided by counselor-type education with counselor-type mediation.

We think that to enable fertile learning educational activities should encourage the learner's *creativity* on various levels that could be monitored from different perspectives including such as output, process, person and environment (Medyna et al. 2009). For developing new computational methods supporting learning we think that there is a lot of unused potential in *collective knowledge* held by a group of learners. We think that there is a need for developing systems that could support processes in which learners could help each other based on their complementing pieces of knowledge and personal strengths that can be gradually collaboratively cumulated. In addition, we think that it is

important to develop especially non-commercial support systems for education that are can be freely used by anyone and flexibly developed further if needed.

We believe that non-commercial support systems can possibly more naturally provide an *objective and neutral approach* to information than commercial support systems since there is no need to have any business model with compromising affiliations. Program code that can be freely distributed and exploited for developing new programs is called *open source*. Some important examples of freely distributable systems and applications that have enabled collaborative development of rich non-commercial modular ecosystems of information processing tools are Unix operating system Linux and Mozilla web browser. In a similar fashion we think that there is now a strong need to actively develop non-commercial modular ecosystems for innovative educational tools. Efforts to increase availability of free and easily usable educational solutions have a great impact for the beneficial growth of wellbeing for everyone but also especially for people living in developing countries, among challenged learners and in general people with special needs in all age groups.

In the recent and still continuing radical period of human history that has brought global connectivity with Internet to almost everyone's reach important actors have also been those who have begun introducing and distributing knowledge with *open access* (i.e. free unlimited access). Although there are still challenges in agreeing about fair ways to protect copyrights and defining reasonable economical compensation mechanisms for authors and publishers of creative work, it seems to be widely recognized that partly uncontrollable distribution of media content has permanently become part of online activity.

Appendix C describes some aspects to motivate the need for open access and open source solutions.

2.3. Identification of learning objectives

A significant and largely referenced yet also criticized classification about learning objectives is *Bloom's taxonomy* originating from a committee of educators (Bloom et al. 1956). Despite its challenges, the original classification work has valuably introduced systematizing efforts to educational research. The model suggests division of educational objectives into cognitive, affective and psychomotor domains. The cognitive domain, often considered the most essential domain of the model in respect to traditional learning, is hierarchically classified to six levels of process. Going from the lowest to highest level they are knowledge, comprehension, application, analysis, synthesis and evaluation. The learners should benefit from cumulatively proceeding from acquiring skills of lower levels to higher levels according to the model. Addressing each learning objectives, the model defines lists of verbs for assessment questions and it defines also suitable learning activities and media.

A later *revision of Bloom's taxonomy* was created trying to enhance earlier expertise in all domains of the model (Anderson & Krathwohl 2001). Among processes of cognitive domain the revised model puts synthesis on a higher level than evaluation and

renames the levels to be remembering, understanding, applying, analysing, evaluating and creating. Furthermore, the revised model defines sublevels for the kind of knowledge to be learned and going from lowest to highest levels of learning they are factual knowledge, conceptual knowledge, procedural knowledge and meta-cognitive knowledge. With a matrix of two dimensions, cognitive process dimension and knowledge dimension, the revised model defines skills with a gradually increasing complexity and the learner should benefit from cumulatively proceeding from acquiring skills of lower levels to higher levels according to the model. Both dimensions of the matrix are further divided to sublevels to address more specifically diversity of educational needs. One of the main contributors for the original framework, Benjamin Bloom, has suggested that “Ideally each major field should have its own taxonomy in its own language—more detailed, closer to the special language and thinking of its experts, reflecting its own appropriate sub-divisions and levels of education, with possible new categories, combinations of categories and omitting categories as appropriate.” (Anderson & Krathwohl 2001)

It has been considered that the educational needs *change along the age* of the learner. Especially when contrasting adults with children, adult learners have been seen as more autonomous and thus benefiting from having learning activities that sufficiently address their individual responsibility and motivation (Knowles et al. 2005). It has been suggested that human cognitive architecture relies strongly on five principles storing information in long-term memory, borrowing and reorganizing information of long-term memory, creation of novel information with randomness, limited capacity and duration of working memory to process novel information, combining working memory and long-term memory to link to and organize environmental information (Blayney et al. 2009). In adoption of knowledge it has been found that learners with lower expertise benefit from having elements of information being presented sequentially in isolated form whereas learners with higher expertise benefit from having elements of information being presented in full interactive form (Blayney et al. 2009).

2.4. Development of computer-assisted education

Developing computer-assisted education is typically motivated by an aim to enable flexible automated learning opportunities for learners and this aim has historical background that carries heritage of scientific revolution and general optimism towards technological advancement. Appendix D describes some aspects about the potential of evolving computer technology.

Influential early work to currently popular learning theories has been done by Vygotsky (Vygotsky 1978) emphasizing that *social interaction* has a fundamental role in learning. Traditionally, especially in authoritative classroom context at school, educational practices have emphasized teaching in which an educator offers new information and practical examples that can be relatively directly and passively adopted by the learner. This type of education has been referred to as a *direct transfer model* of learning. As an alternative for direct transfer model, it has been suggested that in

educational process the learners should be provided with an active role instead of the more traditional passive role. This has induced a need to develop and implement new kind of educational activities that encourage individual *exploration and creativity of the learner*. However, it seems to be challenging to reliably verify if the new innovative learning methods can really offer actual educational gain when compared to more traditional methods.

Computer-assisted learning covers a broad spectrum of methods that aim to support learning with *information and communication technology* (ICT). Many alternative terms can be considered to refer to computer-assisted learning, including for example term e-learning that can be interpreted to originate from learning conducted through electronic media. In a multinational survey of Organisation for Economic Co-operation and Development (OECD) published in year 2005 many educational institutions reported that e-learning has a broadly positive effect on the quality of learning and teaching but *direct evidence of pedagogic value* has remained open question and adoption and use of computer-assisted systems has remained low in many areas, for example 6.6 percent of respondents reported institution-wide adoption of content management systems in 2004 (OECD 2005).

Computer-assisted learning can be seen as a part of long historical development that has aimed to offer learning opportunities with increased freedom concerning temporal and locational distribution of educational resources. Jónasson (Jónasson 2001) mentions based on previous research that already from year 1728 there are published magazine advertisements about *educational correspondence courses* (Holmberg 1986) but the first documented case of two-way communication has been credited to Isaac Pitman's shorthand writing course based on mailing postcards in 1840 (Verduin & Clark 1991). In addition, Jónasson mentions based on previous research (Verduin & Clark 1991) that the first currently known case of using term "*distance education*" has apparently happened in a catalogue of University of Wisconsin-Madison in 1892.

We think that significant inspiration for developing computer-assisted methods for knowledge management can be gained from proposal made already in year 1843 by Ada Lovelace (Lovelace 1843) that is considered to be among the earliest formal descriptions about *principles of an algorithm* and this proposal shows how long-lasting have been the efforts to develop analytical methods to automatically process knowledge in ways that can be advantageous to human well-being. Some encouraging arguments of Ada Lovelace that motivate developing computational models are that:

"In enabling mechanism to combine together general symbols in successions of unlimited variety and extent, a uniting link is established between the operations of matter and the abstract mental processes of the most abstract branch of mathematical science. A new, a vast, and a powerful language is developed for the future use of analysis, in which to wield its truths so that these may become of more speedy and accurate practical application for the purposes of mankind than the means hitherto in our possession have rendered possible." (Lovelace 1843).

Computers have been gradually introduced to schools around the world. The ratio of number of students to number of computers in American schools has been reported to decrease from 125:1 in year 1983 to 20:1 in year 1990 and then to 9:1 in year 1995

(Hamza & Alhalabi 1999). However, an influential early large computer-based instructional system that has been applied in educational work is PLATO system originating already from 1960's and developed at University of Illinois (Bitzer & Skaperdas 1968). Use of computer technology in learning activities at school has gained varied emphasis and still in the beginning of 21st century it has been often carried out without a systematic computer science curriculum (Tucker et al. 2003). Following the principles of traditional teaching methods *computer-based learning/training* typically refers to systems that offer self-paced educational tasks in a relatively linear way about a static educational content somewhat resembling reading a manual book. Originally many solutions for computer-based training relied on local data and data content such as diskettes and cd-roms.

According to surveys, in 1994 about 35 percent of American public schools had access to the Internet, where as in 1995 about 50 percent of these schools had it (Carpenter et al. 1996). In 2009 in American public schools about 97 percent of teachers had at least one computer everyday located in the classroom and internet access was available for about 93 percent of these computers (Tice et al. 2010).

Even if the pace of supplying schools with technology varies in different location around the globe it seems that during last two decades a great number of learners at school became supplied with both an access to a computer and an access to Internet and this motivated creation of forms of *online learning* based on communication over the Web. Since distribution and sharing of knowledge became easier, or at least got a new supplementary channel, with Web various *knowledge management systems* were introduced aiming to help building systematic knowledge resources and exploiting them online for learning. Due to evolution of web technology and increased use of personal communicational devices opened area of *mobile learning* trying to address ubiquitous possibilities for learning and *computer-supported collaborative learning* trying to address learning by supporting organized collective complementing work among the learners. Phenomena of computer-supported collaborative learning has been very closely associated also with such terms as *e-learning 2.0* and *long tail learning* emphasizing the diverse use of social software components including for example wikis, blog, podcasts and virtual worlds. An approach called *blended learning* tries to find an optimal way to balance and integrate computer-assisted learning with practical and class-room based activities.

A meta-analysis of 99 studies (Means et al. 2010) found out that in educational experiments blended learning which combined online and face-to-face instruction outperformed conventional face-to-face instruction. However, it seemed that there is no direct evidence that this advantage was due to the online approach itself being a superior medium. In fact, online learning itself seemed to be about as effective as classroom instruction. In addition, conditions for compared online and face-to-face scenarios seemed to differ and it was likely that online approach included additional resources and used more time. Furthermore many experimental evidence suffered from small sample sizes and there appeared to be little actual evidence gathered directly among elementary and secondary school students.

2.5. Learning by feedback and testing

Kirschner et al. (Kirschner et al. 2006) argue that findings of previous research support direct strong instructional guidance rather than constructivism-based minimal guidance in instruction of novice and intermediate learners, and even for learners that have considerable prior knowledge strong guidance has been found to be equally effective as unguided instruction. When using computer-assisted learning environments, getting encouraging and appropriate *feedback* for the work done so far has been considered as an important factor to enhance learning results. Despite its usefulness, feedback is typically provided after the learner has already made her action and there is need for assistance given already prior action that can be called as *cueing*. In a collaborative multimedia based learning experiment it was shown that both cueing and collaboration can positively influence learning outcomes and that the learners without cueing benefited most from additional collaboration (Hummel et al. 2006).

Transfer of learning refers to application of earlier learning experience in one context to a new learning experience in another context. Butler (Butler 2010) compared retention and transfer of facts and concepts when studying prose passages with repeated testing and repeated studying, and superior results were gained with learning process consisting of repeated testing. Marzano (Marzano 2000) argues that during a grading period from practice session to practice session the amount of learning is large at first but later decreases so that power law can be used to estimate end score. He also mentions that this trend of *power law of learning* is introduced by Newell and Rosenbloom (Newell & Rosenbloom 1981) and that according to Anderson (Anderson 1995) a power function formula $y=mx^b$ can be used to explain how much time in seconds (y) is needed to recognize precisely information that has been presented to a person after various amounts of exposures (x) concerning this information, and parameters m and b can be defined to address a particular type of learning situation. Marzano (Marzano 2000) suggests that same kind of power law formula can be used to estimate gradual increase of exam scores if student learns during a grading period containing intermediary exams each measuring adoption of new knowledge with equal coverage.

In educational field, *multiple-choice questions* have been considered as a convenient way to implement easily automatically gradable tests but however it has been questioned how reliably they can measure the learner's actual understanding about a given topic. Multiple-choice questions typically rely on the learner selecting the most promising option from a limited collection of alternative answers shown to her. In contrast, more open format of answering to tests rely for example on writing short essays or filling empty spaces in sentences without heavy constraints about writing style and this format can be called as *constructed-response questions*. Since grading cannot typically be performed automatically with constructed-response questions, they are often more laborious to implement. Anyway, constructed-response questions have been often considered to test better the deeper understanding of the learner's understanding about a given topic.

An experiment with vocabulary learning in a self-guided web-based language learning environment showed that constructed responses items had greater effect than the multiple-choice items on posttests about recall and recognition of the students (Chen & Chen 2009). In these results, higher cognitive load was reported with multiple-choice items and offering cueing did not give significant interaction effect between item types. Still, there have been efforts to identify links between two assessment metrics, multiple-choice questions and constructed-response questions, for example by addressing distinctive knowledge levels of Bloom's taxonomy but results have been mixed indicating that cognitive mechanisms involved in constructed-response questions appear to be much richer (Kuechler & Simkin 2010). However, there are also claims that constructed-response questions are equal to multiple choice questions that allow multiple responses and use scoring rule counting only correct responses (Kastner & Stangla 2011).

2.6. Learning based on recommendations

Recommender systems are computational systems that are used to filter relevant information items from a collection of information according to criteria matching the needs of the user. Recommender systems typically compare a user profile to some reference features and aims to estimate what new available information items the user might prefer to process next ((Ekstrand et al. 2011); (Ricci et al. 2011)) . These reference features can be based on various characteristic. Depending on the strategy, Burke et al. (Burke et al. 2002) have categorized recommendation systems into five classes that are: collaborative, content-based, demographic, utility-based and knowledge-based. *Collaborative recommendation* emerges from ratings given for items by similarly behaving other users and based on demographic data, *demographic recommendation* from preference of demographic classes possibly without need of ratings, *content-based recommendation* from the features of the items according to the user's ratings of them, *utility-based recommendation* from ranking of items by applying an utility function describing the user's preference, and *knowledge-based recommendation* by finding a match between the items and functional knowledge about the user's needs. In the last two cases, there is a challenge to actually identify suitable representation for utility function and functional knowledge.

Adomavicius and Tuzhilin (Adomavicius & Tuzhilin 2005) consider that algorithms for collaborative recommendations can be categorized into two general classes, memory-based (or heuristic-based) and model-based, and according to them *memory-based algorithms* are heuristics which make rating predictions according to the entire collection of items that has been previously rated by the users, whereas *model-based algorithms* exploit the collection of ratings to learn a model that is then used to make predictions of ratings. Model-based algorithms rely typically on Bayesian models, latent semantic analysis, artificial neural networks, or machine learning methods, for example method called "k nearest neighbors". Recommender systems with the model-based approach are challenged due to its typical requirement of large samples of items to learn

a model reliably. Drachsler et al. (Drachsler et al. 2008) consider that in the near future large experimental samples can be hard to obtain for learning networks and thus they focus on memory-based approach. They also consider that memory-based algorithms can be categorized to *collaborative filtering techniques* and *content-based techniques*, and according to them collaborative filtering techniques can be *user-based*, recommending items rated by users having similar rating style, *item-based*, recommending items receiving similar type of ratings, or *based on stereotypes or demographics*, recommending items preferred by similar type of users, whereas content-based techniques can be *case-based reasoning*, recommending items similar to those the user has liked earlier, or *attribute-based techniques*, recommending items having attributes matching to the user profile.

2.7. Generating recommendations for fertile learning

In a survey comparing four different recommendation techniques and seven different hybridization strategies showed that among *hybrid recommender systems* promising are cascade hybrids and feature augmentation hybrids (Burke 2007). In *cascade hybrids*, recommenders have a strict priority so that the lower priority ones break ties in the scoring of the higher ones. In *feature augmentation hybrids* one recommendation technique computes a feature or features which are then used as a part of the input to the next technique.

Herlocker et al. (Herlocker et al. 2004) have listed six typical types of *user tasks* supported by recommender systems and these six types include recommendations while user carries out other tasks, recommendations as a selected list of suggested items, recommendations as a complete list of related items, recommendations of a sequence of items, recommendations for the users without ulterior motives and recommendations while testing the system's capability. As a supplement to the previous list, Manouselis et al. (Manouselis et al. 2011) name three user tasks considered particularly interesting in technology enhanced learning. They include recommendations of especially new items, recommendations of other users having relevant interests and recommendations of alternative learning paths through learning resources. Manouselis et al. (Manouselis et al. 2011) also suggest identification of the *evaluation methods* that could be engaged to measure the effect of the recommender in a particular context of technology enhanced learning, specification of ways to measure the success of its various components and developing instruments to collect evaluation data in educational settings.

The nature of generated recommendations and even recommender systems can be evaluated with various measures and it has been suggested that the methods relying on collaborative filtering can have an advantage in contrast with the methods relying on content-based filtering when there is a need for recommending *serendipitous items* (i.e. surprisingly interesting items) for the user that she could not have found otherwise (Herlocker et al. 2004). *Strength* of the recommendation can indicate how much the system estimates that the user likes the current item. *Confidence* of the recommendation

can indicate how sure the system is about the accuracy of the given recommendation. *Coverage* can indicate how large domain of information items can be considered when giving recommendations. *Learning rate* can indicate the quality of recommendations and since depending on statistical models the systems typically create asymptotically improving results. Learning rates can be computed in respect to single information items or users as well as the overall system.

Chapter 3. Collaborative educational processes in networks

This chapter introduces current and emerging trends for building collaboratively maintained knowledge structures that can be used flexibly for information retrieval and educational purposes. A promising framework has been wiki technology supporting open access and open source solutions to be implemented. It seems that many knowledge processing tasks can be fruitfully distributed to human actors who can then in self-guided manner produce impressive collective solutions to knowledge management and knowledge maturing. There is a need to develop computational methods that can exploit networks of knowledge and to identify pedagogically rewarding paths to be explored by learners.

3.1. Collaborative sharing of knowledge

It has been long recognized that learning is a highly *individual process* that is influenced by *prior knowledge* of the learner and the context of learning. There is a need for automated methods that can assist individual learners. Despite of benefits getting teaching provided by a human tutor, it is often a question of costs and distribution of resources that suggests that parallel *computer-assisted supportive methods* are needed for learners (Anderson & Jackson 2000).

Especially in *special education* the challenged learners have a strong need for supportive methods and even relatively simple new innovative tools exploiting computer technology can offer significant help (Hasselbring & Glaser 2000). For example to support knowledge acquisition in specific vocabulary learning tasks for visually impaired it has been noted how important it is to provide a tailored auditory vocabulary and spelling trainer (Stein et al. 2011). Another approach is to build systems trying to address more general knowledge acquisition tasks even though compromising somewhat the details and possibly to build it as a mash-up consisting of low-cost generic components (Lahti & Kurhila 2007). Computer-assisted learning can also offer valuable ways to enhance open and distance learning in developing countries (Gulati 2008).

In a meta-analysis Johnson et al. (Johnson et al. 2000) listed ten *cooperative learning methods* that have received a lot of attention in research including Learning Together, Academic Controversy, Student-Team-Achievement-Divisions, Teams-Games-Tournaments, Group Investigation, Jigsaw, Teams-Assisted-Individualization, Cooperative Integrated Reading and Composition, Cooperative Learning Structures, and

Complex Instruction. They found 164 studies that investigated eight of these cooperative learning methods, suitable studies were not found concerning the two last methods. When these eight cooperative methods were compared to either competitive or individualistic learning the greatest effect on achievement was gained with a Learning Together method which is based on setting a goal for group, sharing opinions and materials, dividing labour and reward.

There have been many initiatives for computer-assisted learning methods introduced in the past. One key challenge has been high *development costs* to build a system that assists learning in a pedagogically meaningful, not just trivial, way. Typically it has been challenging to develop adaptive systems that can offer varied inspiring perspectives to the learning topic. Often the old systems have required making laborious *manually tailored design* with careful effort of human experts to address a specific learning topic and when exploiting the system it has usually provided to the learner somewhat the same educational knowledge every time with about the same formulation. It has been difficult to introduce new knowledge to a learner gradually so that the learner's prior knowledge and needs have been taken into account fruitfully *preserving logic and continuity* and providing an optimal increase in the level of complexity. Besides just giving pieces of new information it has been challenging to find suitable ways to provide *personal choices* for the learner. For example exercises have often remained relatively monotonic and alternative ways to approach the same topic has not been often highlighted easily.

Often old systems developed to support learning have provided only one possible solution and one possible chain of answers or one possible type of modular, gradual building process to reach accepted solution. Systems have not usually been able to offer easy, intuitive *recommendations* for the learner how to proceed pedagogically in her personal learning process. It has also been challenging for the systems to offer methods for *collaboration* that efficiently and fruitfully combine complementing resources of individual collaborators. A promising largely adopted relatively recently developed scheme for combining individual resources in collaborative knowledge construction process are *wikis* that are web environments enabling free asynchronous editing of shared knowledge in a web site with a constant access to full edit history thus enabling to analyze the cumulative growth of information and reverting to previous versions of work in progress.

Beside active adoption of wikis, there have been various alternative proposals how to support collaborative work with computational methods. One example of interesting approaches is open-source tool Geogebra that has been developed for collectively building and sharing *visualizations* of mathematical ideas (Hohenwarter & Jones 2007). Kittur et al. (Kittur et al. 2011) have proposed a framework for accomplishing collaboratively distributed complex tasks using so called *micro-task markets*. With this approach collaboratively written articles were rated more highly and had lower variability than individual written articles and were rated having similar quality as simple articles of the Wikipedia. Based on hierarchical cluster structure of network, Yasui et al. (Yasui et al. 2009) have proposed a method for identifying *key persons* and

key terms of a discussion in online collaborative environments by mutually reinforcing relationship between persons and terms.

3.2. Collaborative knowledge processing

Various theoretical frameworks have been introduced trying to increase understanding about collaborative processes and to develop supportive methods for organizing and coordinating collaboration. *Knowledge management* aims to model practices of collaboration and innovative work in organizations trying to find solutions taking into account many practical restrictions and requirements concerning corporate life for creative work. We think that a promising direction for developing methods for computer-assisted learning is *human-based computation* which means computational techniques in which operations performed by computer are augmented with human resources. Wightman (Wightman 2010) categorized systems that crowdsource human-based computation into four classes based on two dimensions which were the type of motivation the user had for completing the task (*direct or indirect motivation*) and whether completion of the task was competitive (*competitive or non-competitive tasks*). He positioned Wikipedia online encyclopedia into the class of non-competitive direct motivation tasks.

For collaborative and creative work there are diverse sources of *motivation* giving the driving force to proceed toward new solutions. The basis of motivation can be difficult to identify but a person's direct motivation for choosing and contributing to a specific work can be seen to originate from some kind of love or passion leading to a voluntary devotion. On the other hand, a person's indirect motivation for working can be seen to originate from getting some benefits or compensation from contribution, for example in the form of economical wealth. Thus, a salary can help to get people to participate in a work but it cannot guarantee the quality of contributions especially when the quality is difficult to measure like in creative work. Anyway, the need to accomplish tasks exceeding the capacity of an individual and requiring diverse resources has led to formation of *communities* that enable individuals to complement each other's skills and knowledge and offer compensation for that.

Computational solutions have been developed to support *creative problem solving* relying on methods that try to enhance free thinking and associations and developing ideas further with specific guided processes. Some methods aim to be very unconstrained and keep criticism at low level like *brainstorming* relying on collective ideation that is progressively iterated to agreed solutions. When comparing nine different procedures for collaborative idea generation, it was found that the groups supplied with a facilitator produces several times more unique ideas than groups without a facilitator (Isaksen & Gaulin 2005). In groups having a facilitator, the highest number of unique ideas was produced by brainwriting method in which ideas written on paper were exchanged and also facilitator participated in writing. In groups without a facilitator, the group which was asked to follow brainstorming guidelines but work independently produced the highest number of unique ideas, followed next by a group

instructed to engage in free discussion and then by a group performing brainstorming as a group. One computational approach to creative problem solving is offered by so called *expert systems* containing a broad collection of *axioms* and *heuristics* often manually coded to the system that can be used to build answers.

There have also been efforts to analyze and identify general, possibly universal, patterns of evolution, innovation and creativity that could be modeled and replicated in future work. For example after identifying key features and principles of an *innovation* they could be generalized to generate other resembling innovations. One early and still influential work in this field is problem solving methodology called TRIZ (abbreviated from Russian term “teoriya resheniya izobretatelskikh zadatch” called in English as the theory of inventive problem solving) that is derived from the study of patterns of invention in the global patent literature and that has emphasized algorithmic approach to the invention of new systems (Nix et al. 2011). When evaluating four possible predictors to predict *problem-solving efficacy* in collaborative group discussions, Voiklis et al. (Voiklis et al. 2006) considered four features: convergence value representing group’s ability to approach solution, frequency of convergent interactions, relative frequency of convergent interactions, and difference between the number of convergent and divergent interactions. They found out that only the convergence value managed to recapitulate enough ontological and causal history to predict significantly problem-solving efficacy.

In complex problems, *genetic algorithms* and related *evolutionary computation* have been used to mimic the nature’s evolutionary process to find solutions. Solutions are generated with a methodology analogous to genetic engineering so that data is transformed through phases of recombination and mutation, and a natural selection process is carried out with some kind of fitness function. In *interactive genetic algorithms* the fitness function is replaced with interactive evaluations carried out by human users (Banerjee et al. 2008). In an early important work, a computer program asked a single human user to serve as a fitness function of an evolutionary algorithm (Dawkins 1986). Term *human-based genetic algorithms* has been used to refer to algorithms engaging a great amount of human participation so that phases of recombination and mutation are carried out through human innovation and natural selection through selection done by human decisions (Kosorukoff 2001). Takagi (Takagi 2012) argues that since in *interactive evolutionary computation* human evaluations are used to optimize target system it is possible then to analyze the target system to understand the human’s evaluation metrics or mechanisms, like in reverse engineering.

Swarm intelligence is a domain of artificial intelligence composed of agents following relatively simple rules forming together without centralized co-ordination entities in which collective intelligent behavior emerges. Analogous to a gene as a molecular unit of heredity, Dawkins (Dawkins 1976) introduced a term *meme* to represent a basic unit of cultural evolution. *Memetic algorithms* introduced by Moscato (Moscato 1989) refer to methods combining genetic algorithms to individual learning methods that can do local refinements and thus aiming to mimic cultural evolution. A range of *adaptive memetic algorithms*, belonging to *hybrid evolutionary algorithms*,

have been developed with an emphasis on the choice of local search methods or memes which has shown to have a significant effect on the performance of problem searches (Ong et al. 2006). Malone et al. (Malone et al. 2010) suggest defining so called *genes of collective intelligence* that can be used to classify collaborative activities based of four factors: what, who, why and how.

3.3. Organizing collective knowledge

Surowiecki (Surowiecki 2004) presented arguments supporting existence of *wisdom of crowds* giving essential criteria for its emergence that are diversity of opinions, independence, decentralization and aggregation. To enhance innovation, Johnson (Johnson 2010) encourages to position creative work into collective networking environments that enable to identify unexplored adjacent possibilities. Hendler and Golbeck (Hendler & Golbeck 2008) emphasize the need for combining two different networking spaces that originate in the social link structures of the social web applications and the semantic link structures of semantic web applications.

Bush and Mott (Bush & Mott 2009) argue that truly open, modular, and interoperable *learning ecosystems* are needed providing learner-centric content that can be reused, revised, remixed, and redistributed easily with tools and content that are seamlessly plug-and-playable supporting agreed technological, usability and accessibility standards. Tapscott and Williams (Tapscott & Williams 2010) suggest that the modern society is currently experiencing a transition to the age of *networked intelligence* that can revolutionize collaborative management and organizational life. They argue that this new era is largely influenced by solving problems with mass collaboration of individual actors that is referred to as *wikinomics*.

Term *open source* that has been largely used to refer to freely distributed and share program code can in broader context used to refer to methodology of work that produces material and services that are provided publicly so that they can be used freely by anyone. Term *open access* is typically used to refer to a practice of providing free access to information sources, such as publications. Having such web content available that supports free use of and free access can be seen as a valuable way to increase equal opportunities for learning and overall sustainable development of society. Collectively produced work and generation of content with it has been called *crowdsourcing* when emphasizing an organization's outsourcing of some work to loosely defined group of voluntary people. Work of an open source movement is usually coordinated by the members of collaborating community themselves whereas crowdsourcing is often coordinated by a representative of an organization outsourcing the work.

When individuals retrieve information from Internet it largely consists of web browsing by using *search engines* and traversing hyperlinks connecting web pages.¹⁰ A

¹⁰ Even large knowledge entities, such as complete educational book series, videos and exercises, can be technically easily exchanged among learners and educators over the Internet by email or through file transfer protocols and file sharing web sites, but unfortunately due to complex *copyright issues* and lack of suitable online retailers many useful knowledge resources cannot be currently legally accessed online. Thus there is a need to develop legally flexible ways to distribute and redistribute educational material.

popular form of crowdsourcing in web environment is *social bookmarking* usually meaning personal *annotation* of preferred and recommendable web sites with a set of tags that are often category names in a process called *tagging*. In contrast with file sharing, social bookmarking does not deliver actual content but instead only a reference to it. Categorization can be based either on predefined fixed set of tags or support free creation of new tags by users as needed offering wider diversity and flexibility but introducing challenges of how to guarantee consistent systematic naming that manages also synonyms and otherwise conflicting naming strategies.

Besides providing just single link recommendations, social bookmarking offers a possibility to analyze link structures on broader scale. For example, social bookmarking enables to identify groups of related web sites linked together and agglomerate and cumulate condensed essential parts of networks describing knowledge. By analyzing *hierarchies* and *clusters* of these networks it is possible to generate categorization and chaining of pieces of knowledge that can be useful for individuals searching for information. To carry out this kind of analysis, there is a need for developing processes that enable selection of most promising pieces of knowledge among alternatives and that can incorporate ranking and competition.

There is also a need for developing methods for smooth joining, reordering and enhancing pieces of knowledge to form *logical entities* of knowledge with continuity that can be shown to the individual searching for information. To enable this can require adaptation of pieces of knowledge depending on the context and based on the characteristics of the individual. For example, currently popular search engine Google (<http://www.google.com>) claims that the original Pagerank method that it has used to rank a web page relies on the number and authority of arriving links to this web page and we think that this method can be seen somewhat analogous to social bookmarking (Brin & Page 1998).

Organizing knowledge to meaningful constellations in a collective process of a group of individuals is carried out by parallel individual human neural systems. Each individual neural system obviously emphasizes doing its own share of the collaborative work thus paying attention to participate in coordination and complementing meaningfully others concurrent efforts. Despite sharing the work each individual neural system apparently tries to maintain a holistic understanding about the knowledge management and its aims. We think that it is possible that the knowledge management processes of collaborative work have some similar fundamental properties with the information processes of reasoning and creativity that are manifested in each individual neural system. We think that some motivation for this suggested correspondence can be based on general characteristics of network architectures called as *small-world networks* that seem to manage to represent quite well knowledge processing on various levels of abstraction ranging from structural and functional properties of human brain networks (Wang et al. 2010) to social networks of people (Uzzi et al. 2007), wikis (Mehler 2006) and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009).

We think that development of new computational methods relying on network representation of knowledge can have an important role in increasing understanding

about how collaborative knowledge management process and individual information processing in neural system are related. In this development work we consider that the Wikipedia offers a unique resource of collectively cumulated knowledge and we think that valuable features that can contributing to educational potential of the Wikipedia can originate from the notion that the Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)). According to Bullmore and Sporns (Bullmore & Sporns 2009), some studies indicate scale-free properties in functional brain networks ((Eguíluz et al. 2005); (Van den Heuvel 2008)) while some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Earlier research trying to mimic the natural process of human neural systems with computational methods has relied on for example *artificial neural networks* and *machine learning techniques*. Important models of probability theory used for creating computational representations about real world decision-making processes include *Markov models* and *Bayesian models* (Buntine 1994). Our research aiming to develop network based methodology for computer-assisted learning is inspired by the *spreading activation theory* of memory (Anderson 1983) that is a cognitive model suggesting that information is encoded in a network of interconnected cognitive units which have an ability to spread activation to related units to form activation patterns that represent specific conscious experiences. Based on meta-analysis considering 135 tasks it has been suggested that each brain area is redeployed to support other cognitive functions and more recent functions of cognition utilize increasingly scattered brain areas (Anderson 2007). Dix et al. (Dix et al. 2010) proposed methods using spreading activation to link external knowledge repositories to personal ontologies based on activation of entities already held in memory and experimentally showed that working set of highly activated entities is typically small.

3.4. Personalized guidance for the learners

Intelligent tutoring systems or *intelligent tutors* are pieces of educational software created to support education with computational models about learning process. Typically they are student-centered rather than teacher-centered and have dynamic models trying to represent essential educational knowledge the student should learn, how the student can reason and how new knowledge is filtered and integrated to the student's existing cognitive structure and reshapes this structure (Woolf 2009). Intelligent tutors can take various forms depending on the features and representations that need to be addressed in the educational setting. Efforts of building intelligent tutoring systems has been supported by already an early experimental finding that an average student receiving individual instruction by a tutor outperformed 98 percent of the students receiving instruction in a conventional classroom setting (Bloom 1984).

There is trend that new terminology is actively introduced to differentiate consecutive development stages of computer systems and methodology although differences are not often clear and thus terminology is overlapping. Even if intelligent

tutoring systems can seem to be a bit old-fashioned term we consider it as a simple descriptive overall naming that we have liked to use to refer to the methods we have developed in our research. However, it should be noted that intelligent tutoring systems in general and in our work especially can contain and mix many features that make them closely related to domains often referred to as instructional design, microworlds, cognitive tools and guided discovery learning. In our work intelligent tutoring system aims to offer an intelligent learning environment relying on computer-supported collaborative learning and adaptive hypertext.

Intelligent tutoring systems typically consist of few complementing models to help processing educational scenario with manageable modules and hierarchy. A relatively common practice is to separate three perspectives: domain model, student model and pedagogical model. *Domain model* aims to represent the structure of the learning domain with educational content, *student model* aims to represent information about the learner's current knowledge (or knowledge level) about learning domain, and *pedagogical model* aims to represent knowledge about how to tailor presentation of educational content according to student model. A traditional approach is to create domain model according to knowledge of a human expert in this field and to use a subset of this domain model as a student model which can be referred to as an overlay student model (Jeremic et al. 2012). Since domain model has a crucial role as a basis for interference and predictions concerning the learner's interaction with the system there is a need to develop systematic processes that can guarantee quality of domain model. Kump (Kump 2010) suggests methods and techniques for validation of different features of a domain model in an adaptive work-integrated learning system that should enable formative evaluation leading to concrete implications of revising the model.

It has been long recognized that gaining fluent skills to read and to express oneself with language are motivated by rich communication (MacWhinney 1999). This implies that varied *collaborative environments* should be introduced to everyday activities of a learner. Besides face-to-face communication also web-based collaborative platforms can provide additional support for challenged learners (Chou & Liu 2005). Since interpreting and understanding natural language still mainly remains as an unsolvable computational problem, in current research it seems feasible to focus on developing support systems that enhance learning processes on relatively general level instead of trying to mimic the evolution of learner's knowledge with vague models about for example consciousness. With a general approach we try to avoid forced learning paths and triggers that often plague educational software and instead we try to activate learner's own motivation, inspiration and problem solving skills.

Successful learning requires systematic introduction of new concepts to the learner so that they can be carefully associated with previous knowledge (Marzano 2004). There is a need for frameworks to support *personalized adoption* of new knowledge that matures along the learners in a synthesizing way (Collins & Halverson 2010) and *collaborative construction* of knowledge resources (Manouselis et al. 2010) supplied with sufficiently converging *free exploration* and recommending connections that are currently most potential for the learner's needs.

Among many competing learning theories *constructivism* has remained widely supported. In brief, it states that humans generate knowledge and meaning from their experiences. Holmes et al. (Holmes et al. 2001) suggested an expanded definition of social constructivism that could fully address the synergy between advances in information technology and virtual environments. One general challenge comes from the long-lasting debate if semantic structures of natural language are independent of syntactic structures or not (Peregrin 2010). *Transferable learning* that enables applying previously acquired training successfully for novel future events can be achieved through the learner being exposed to the learning material in a variety of contexts (Schmidt & Bjork 1992). Designing learning activities can exploit the notion that people typically predict upcoming words in fluent discourse (Van Berkum et al. 2005). There is evidence that concept-oriented reading instruction increases reading comprehension and engagement (Guthrie et al. 2004).

Serrano et al. (Serrano et al. 2009) argued that some key regularities of written text concerning burstiness of words, topicality and their relationship can be modelled with two simple algorithmic techniques that are *frequency ranking* with dynamic reordering and *memory effect* connecting word frequencies across different documents. They suggest that their model enables to relate two key mechanisms that have been assumed to affect how humans process the lexicon: rank frequency and context diversity. They propose using their model to study coevolution of content and citation structure for example in the Wikipedia. In a resembling fashion, in our research we believe that learning can be successfully supported with a similar approach and thus have developed methods that use rank frequency and context diversity of the Wikipedia enabling a learner to process lexicon to a pedagogically rewarding structure.

Creative learning strategies are needed to boost creative thinking by helping the learner to get inspiration, to achieve a new perspective and to focus her attention to things that support creation of a new idea (Hilliges et al. 2007). As a computational approach for semantics Gärdenfors has suggested a model of *conceptual spaces* for representing the meanings of different kinds of linguistic expressions (Gärdenfors 2004). In addition, Fauconnier and Turner have argued about the human talent to create *great arrays of conceptual variety* that can be compressed into manageable regularities and connected to large mappings (Fauconnier & Turner 2008). Also, Gero's *Function-Behaviour-Structure model* of conceptual design has offered methodology to manage with creative process (Gero 1990).

3.5. Representations of collaborative knowledge

In computer-assisted education, a strong trend is to develop *learning objects* that are modular resources designed to explain learning objectives and *intelligent tutoring systems* that provide automated guidance like an experienced human tutor. For a pedagogically motivated and tailored learning experience, *visualizations* in many forms can support knowledge management (Eppler & Burkard 2006). Various compact notation techniques, such as diagrams and flowcharts, are used to compress information

to more manageable units and to highlight essential relations. However, punctuality becomes easily sacrificed and it is challenging to find a good balance with compactness and detailedness in visualization. We think that new domain-independent adaptive methods are needed to manage knowledge with a compact notation that has an optimal expressiveness. Interpreting compact notations is often easiest for people having a shared history although creative work benefits from varied backgrounds. We think that concept maps are an illustrative and adaptive notation technique that should be increasingly exploited to support collaborative creative work.

Despite the broad usage of *concept mapping*, all the potential of this compact notation has not yet been unleashed (Bonastre & Pina 2005). Concept maps are graphical visualizations that typically consist of nodes labeled with concepts that are connected with directed labeled arcs depicting the relationships between concepts. Concept maps have resembling variations, including mind maps and semantic maps, having diverse alternative definitions and having been used for long time with positive reception in education ((Johnson et al. 1986); (Novak & Gowin 1984); (Al-Kunifed & Wandersee 1990)). Concept maps have been suggested to suit better for reviewing activities in the classroom than for individual vocabulary learning strategies (Nielsen 2002) but on the other hand also to support vocabulary instruction for students with learning difficulties (Baker et al. 1992). Stahl and Vancil (Stahl & Vancil 1986) found out that to use semantic mapping effectively in vocabulary instruction it needs to be supplied with a discussion and that instruction relying just on discussion can offer similarly effective results. Concept maps have been also promoted for active use in visualization of scientific research (Wheeldon & Ahlberg 2011).

By building and modifying a visual concept map each learner can express and reflect her own *mental conceptual structures*: what are the meanings for each concepts and how they are related. In addition, the process of building a concept map allows to explore alternative conceptual structures and to compare them flexibly in a constructive manner. Especially when collaborating using a shared concept map, the learners can complement each other fruitfully by providing feedback and further ideas. Also automated evaluation of built concept maps (La Vecchia & Pedroni 2007) and solutions addressing special needs (Blenkhorn & Evans 1998) have been proposed.

According to a classical but criticized theory, *concepts* are structured mental representations that encode necessary and sufficient conditions for their application (Laurence & Margolis 1999). In computational natural language processing, the ambiguous *mappings* of words to concepts are often analyzed as *correlation patterns* in large text samples. Online knowledge resources have received increasing attention since they can be easily accessed and updated by anyone. In digital format related pieces of knowledge can be versatilely connected with *hyperlinks* thus forming networks. *Semantic features of networks* have been modelled from various perspectives including learning, graph-based representation and information flows ((Gladun et al. 2007); (Baget et al. 2008); (Erétéo et al. 2009)). Based on statistical analysis and probabilistic methods, models have relied on lexicographical resources like WordNet (Fellbaum 1998), manual statements like in CYC project (Lenat 1995) and the contents of the Wikipedia (Kröttsch et al. 2007).

Anyway, it has remained challenging to automatically *extract semantic knowledge* from natural language documents. Computational language models have used for example n-grams and hidden Markov models, as well as various tagging and parsing techniques. A common assumption has been that co-occurrence of certain words in small observation window and in specific order indicates their semantic relatedness and similarity. However, indexing word distributions from large corpuses typically results in sparse high-dimensional vector spaces that are often inefficient in making searches and comparing distances, despite of advancement in dimensionality reduction techniques. *Categorization of documents* often relies on weighting and ranking matching documents. Two basic trends are *statistical indexing* and *intelligent indexing*. The former approach has suffered from unrealistic assumption of independence of the index terms. This has encouraged the latter approach which consists of conceptual and semantic indexing (Wang & Brookes 2004).

Text classification has strongly relied on so called “bag of words” approach combined with for example k-nearest neighbour algorithms, support vector machines and artificial neural networks. Thus, usually only words explicitly mentioned in the text fragments have been considered, assuming the vocabulary to be consistent everywhere. Knowledge resources used for creating classification models have often had a limited coverage and challenges to be updated. Also the agility to both generalize and differentiate has been limited. *Tf-idf weight* (i.e. term frequency – inverse document frequency weight) is a general statistical measure for evaluating how important a word is to an article in a collection of articles (Salton et al. 1988). It reaches high values if the word appears frequently in the article but rarely in the whole collection. Network models enable many linking schemes to express parallel semantic relations between textual items on various levels of abstraction and to tolerate possibly overlapping and fuzzy categorization. In article networks, *Pagerank* is a popular measure used to denote importance of an article based on the amount of arriving links and their corresponding value. An old interpretation is that the Pagerank value of an article can express the chance that a random surfer will arrive to this article through a link (Page et al. 1999). Both tf-idf and Pagerank measures have a limitation that to work well they initially need to perform a computationally heavy indexing through the collection of articles.

One computational approach often referenced as “*semantic web*” relies on building a common model of knowledge, so called *ontology*, by defining simple relation statements that link concepts. There are challenges to ensure coherent categorization when combining statements from varied human contributors and to deal with ownership and neutral management policies of collaboratively built knowledge resources, such as Open Directory Project (Hammond et al. 2005). Maintaining a constant update rate can be difficult for many initiatives. Besides defining relation statements manually, ontologies can be extracted from web content labelled with community generated tags (Nauman et al. 2008). This metadata actively produced by bloggers and social bookmarking creates collections of *folksonomies*. However, loose coordination and non-explicit criterion induce ambiguity reflecting varied individual preference and experience. Abuse for search engine optimization and anonymity of collaborators can also reduce reliability of tagging.

To bring structure to the meaningful content of web pages, so called semantic web approach aims to introduce ontologies as a formal representation for concepts within a domain and the relationships between them (Berners-Lee et al. 2001). However, many traditional ontology projects have received criticism about being too closed, formal and hard to update (Simperl & Tempich 2006). Zouaq and Nkambou (Zouaq & Nkambou 2009) proposed a method to automatically generate a domain ontology from plain text documents and use this ontology as the domain model in computer-based education. They suggested evaluating the generated domain ontology with three dimensions: structural, semantic, and comparative.

To manage knowledge structures, ontologies try to offer formal explicit specification of a shared conceptualization. Knowledge structures can be intuitively visualized with *concept maps* typically consisting of nodes labeled with concepts connected with labeled directed arcs depicting their relationship.

3.6. Knowledge resources based on wiki technology

Wikis are collaboratively created and edited interlinked web sites with simplified markup language and full browsable edit history. Wikis have opened useful approach for asynchronous generation and editing of knowledge as well as a fascinating research domain concerning collaborative knowledge maturing process, inspired by the rise of the Wikipedia online encyclopedia. Creation of the first online wiki service, taking place in 1995, has been credited to Ward Cunningham who has been quoted describing wiki as “the simplest online database that could possibly work” (Leuf & Cunningham 2001). Etymologically wiki refers to a term meaning quick in Hawaiian languages. For clarification, a preferable spelling is wiki (with plural form wikis) although sometimes alternative spellings can be seen in literature and have been used also in our previous publications (such as considering this word as a proper noun Wiki and using plural forms wikies/Wikies). Collaboratively maintained web sites of wikis have been actively adopted as new educational environments with an assumption to support constructive learning process. However, typical use of wikis may enhance merely student engagement, but not performance on assessment (Neumann & Hood 2009).

Cress and Kimmerle (Cress & Kimmerle 2008) presented a theoretical framework describing how learning and knowledge building process can happen in the social system of wiki and the cognitive systems of the users. Based on empirical analysis of using the Wikipedia, they suggest that individual learning can emerge due to *equilibration activities* caused by subjectively observed incongruities between the individual’s knowledge and the wiki’s information. It has been suggested that wiki environments work best with organizations who don’t have strict hierarchy and who can agree about working guidelines and conflict resolution mechanisms, typically requiring that all aspects of controversial topics need to be covered (Todorov 2009). There has been an attempt to develop tools that support building and exploring semantic knowledge structures with wiki technology and that can offer shallow learning curve and expressiveness of natural language (Kuhn 2009).

Bauer (Bauer 2007) showed that machine learning techniques can be successfully applied to classify semantic relations from the hyperlink structure of the Wikipedia and found that simple *lexical features* are suitable for detecting hypernym but significantly worse for hyponym, possibly due to hyponyms being often in lists that offer limited context to be extracted. Features generated from *categories* are usable but worse than lexical features. The chosen vector representation introduced sparseness of feature representation but was still manageable for both support vector machines and decision trees. Support vector machines performed slightly better but decision trees achieved higher precision yet compromised with lower recall.

Our work relies on assumption that exploiting wiki based knowledge resources can be a promising way to build, explore and adopt knowledge. An important earlier work having resembling to our proposals is a hypothetical system called *Memex* suggested and introduced by Vannevar Bush (Bush 1945) (Vannevar Bush spells the name with lower case letters, i.e. memex). Memex was described as a device based on microfilm technology enabling an individual to store all her books, records and communications and this knowledge entity could be consulted fast and flexibly as a supplement to one's memory. So called associative trails could be created by an individual by chaining links across an arbitrary sequence of frames of knowledge supplied with personal comments and side trails. The idea of Memex has been said to have been directly influencing on the development of hypermedia and hypertext systems leading to the introduction of the World Wide Web. However, it seems that typical hyperlink architecture of the Web has relied on relatively mechanical hierarchy of indexing that is challenging for semantic exploration of knowledge and it has not been until emergence of wiki architectures and the Wikipedia when the Memex's idea of associational linking across pieces of knowledge has become easily available. One of the Vannevar Bush's inspiring predictions is that:

"Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified." (Bush 1945).

Thus for us it appears that Vannevar Bush has already long before online learning era suggested methodology for personalized exploring in knowledge structures relying on collectively built cumulative complementing pieces of knowledge.

Open access and *open source* movement has revolutionized availability and distribution of knowledge and one of the most promising and popular ones is the *Wikipedia* online encyclopedia (<http://www.wikipedia.org>). Supported by a non-profit Wikimedia Foundation (<http://wikimediafoundation.org/wiki/Home>), the Wikipedia is a multilingual project containing 286 language editions having altogether about 28.6 million articles that have cumulatively reached about 1.65 billion edits as of August 2013 (List of Wikipedias 2013). According to Alexa Internet's web traffic reports the Wikipedia is about the seventh most popular web site globally, and a visitor spends daily approximately 4 minutes and 36 seconds on the site, there are about 3.71 pageviews per visitor and about 53 percent of visits contain one pageview only (Alexa Internet 2013).

Wikimedia Foundation maintains a diverse collection of encyclopedic projects related to the Wikipedia that partially share same resources and for example among different language editions there exist natural overlap about article topics and content. In August 2013, eight language editions (English, Dutch, German, Swedish, French, Italian, Spanish and Russian) contained over 1 million articles, 46 language editions over 100000 articles, 120 language editions over 10000 articles and 223 language editions over 1000 articles (List of Wikipedias 2013). Foundation of the Wikipedia has been credited to Jimmy Wales and Larry Sanger and formal launch happened on 15th of January 2001. In our Wikipedia related research started in 2008 we have decided to focus our analysis only on the biggest language version *English edition of the Wikipedia* (<http://en.wikipedia.org>) that has grown during our five years of research from about 2.1 million articles in January 2008 to about 4.3 million articles in June 2013 (Wikipedia statistics 2013).

The members of Wikimedia Foundation and active volunteers have formed an organizational structure for coordinating development of the Wikipedia. New features have been introduced to the layout of article pages of the Wikipedia along the years, also during the preparation of this dissertation. For example there has been evolution in functionality of so called infoboxes and navboxes that are standardized visual components which have been increasingly added to article pages to represent some key facts and related hyperlinks in a compact form. Responding to many earlier suggestions about enhancing the ways to measure quality of the Wikipedia's content, in September 2010 a new feature called Article Feedback tool was first time deployed in a collection of English Wikipedia articles, and its use was expanded to about 100 000 articles by May 2011 (http://www.mediawiki.org/wiki/Article_feedback). We would not be surprised if some pedagogically motivated features or visualization techniques related to ones we have suggested in our publications [P1]-[P8] would appear some day in the future to the layout of the Wikipedia, at least as alternative supplementary add-ons.

In close relationship with Wikimedia Foundation is a collaborative platform *Wikimedia Toolserver* (<http://toolserver.org>) operated by registered association "Wikimedia Deutschland e. V." which hosts and supports various software tools for contributors. Besides gathering and maintaining cumulative logs of data about the current state and historical evolution of the knowledge structure of the Wikipedia and patterns of retrieving articles by readers, community surrounding Wikimedia Foundation offers open solutions to analyze also emerging trends and information needs that are not yet satisfied. It is possible to retrieve listings about most wanted still currently missing articles (http://en.wikipedia.org/wiki/Wikipedia:Most_wanted_articles).

Based on planning among ordinary community members, a Strategy Task Force formed in February 2010 has formulated *development goals* for the Wikipedia for the next five years, including the following: increasing reach, improving content quality, increasing participation, stabilizing infrastructure and encouraging innovation (http://strategy.wikimedia.org/wiki/Strategic_Plan/Movement_Priorities). In September 2011 Wikimedia Foundation introduced a new educational application QRPedia which enables retrieving supplementing information from the Wikipedia for any encountered

physical object that is supplied with a specific quick response barcode (QR code) tag that can be read by the camera of a smartphone (Wyatt 2011). This QRPedia application has been already adopted by some public institutions and it has been considered promising for example for galleries, libraries, archives and museums. In September 2012 Wikimedia Foundation announced that they make publicly available anonymous search log files for Wikipedia and its sister projects thus opening new opportunities for analyzing populational patterns and trends of search queries made to exploit encyclopedic knowledge (van Liere 2012).

Reliability of the Wikipedia's factual contents has been questioned but there have been verifications indicating the reliability to match traditional encyclopedias ((Giles 2005); (Chesney 2006)). The *coverage* when measured with the number of entries has already become much greater in the Wikipedia than any traditional encyclopedia and possibly any previously existing encyclopedia (for example English edition of the Wikipedia having 4.3 million articles in June 2013 whereas recent print editions of Encyclopaedia Britannica contained about 65000 articles (Berinstein 2006)). Also continuing relatively high rate of growing and updating is typically differentiating the Wikipedia from all other information sources of its kind. The number of articles in the English edition of Wikipedia (4.3 million articles in June 2013) has become higher than some estimates about an average human vocabulary (for example Nation and Waring (Nation & Waring 1997) suggest that a university graduate has a vocabulary of about 20000 word families). What is especially interesting is that the *full edit history* of Wikipedia articles can show how pieces of knowledge have been agglomerated and edited by collaborative authors gradually in a voluntary refinement process and linking and various categorizations have been established thus grouping and associating various terminological and thematic topics. Due to lucky discovery in 2010 of very early edit history data that was already thought to have been permanently lost from the early months in 2001 made it appear that full continuous edit history of whole Wikipedia so far has been successfully archived (Starling 2010).

It can be seen from evaluations carried out in 2007 and 2012 that during five years in between general attitude towards *educational use* of the Wikipedia has become increasingly accepted and despite earlier skepticism nowadays many schools and educational authorities have promoted various initiatives to exploit Wikipedia and its related projects to support learning ((Konieczny 2007); (Konieczny 2012)). Cosley (Cosley 2006) offered theoretical and experimental indications showing that the strategy used also by the Wikipedia to publish all contributions instantly instead of a pre-review process accumulates value faster to community but after passing certain threshold of generated value the growth diminishes and it might be beneficial to switch to pre-review policy. Despite the fact that the contents of the Wikipedia can be freely edited by anyone it has been found out that only a small portion of editors account for most of the work actually done and the value actually produced ((Pancier et al. 2009); (Nagaraj et al. 2009)).

3.7. Using the Wikipedia as a conceptual network supporting education

A leading wiki site, the Wikipedia online encyclopedia, provides an extensive coverage of factual knowledge from various domains of life and is actively used as a resource by students and educators. Despite the concerns of accuracy, missing reference and vandalism, the content has been shown to be relatively reliable and up-to-date (Chesney 2006). The content can be added and edited collaboratively by anyone but some parts are more protected to prevent vandalism and consistent rewriting. General usage patterns for various Wikipedia editions have been analyzed (Reinoso et al. 2009) showing a ratio of 620 reading operations per one saving operation for articles in the English edition.

We think that collaboratively built Wikipedia online encyclopedia has revolutionized gathering and sharing knowledge with open source movement. The maturing process of an individual to adopt knowledge can be paralleled with the development of knowledge of the population. The cultural evolution, creative experimentation and documentation have enabled gaining new understanding about principles of life and building lasting knowledge structures that can be passed to new generations. We think that the foundation of Wikipedia and its building process can be seen to demonstrate the building of an inventory of essential *human knowledge*. The decisions intuitively done by a diverse collective of contributors concerning what kind of pieces of knowledge should be added and edited in this knowledge entity, how to cross-link them and in which order these actions appear can be seen to represent an average mutual agreement about how most valuable pieces of knowledge and their linking emerge and interact in human consciousness. Therefore we think that the learning processes of a human individual and adoption of conceptual knowledge by children along their early years can be paralleled with the mechanisms and patterns that can be identified in the gradually step by step advancing building stages of the Wikipedia.

We do not claim that the conceptual network of the Wikipedia is capable to mimicking the intellectual abilities of a human mind but anyway we suggest that it is reasonable to suppose that thinking and understanding performed in human mind largely deal with conceptual dependencies, relations and causalities that can be fruitfully compared and supported with *conceptual structures* emerging in the Wikipedia. We motivate our suggestion with findings that small-world topology has been identified structurally and functionally in human brain networks (Wang et al. 2010) as well as in the Wikipedia (Ingawale et al. 2009), and that also scale-free properties have been possibly identified in functional brain networks ((Bullmore & Sporns 2009) referring to ((Eguíluz et al. 2005); (Van den Heuvel 2008); (Achard et al. 2006); (Bassett et al. 2006))) and surely identified in the Wikipedia ((Zesch & Gurevych 2007); (Masucci et al. 2011)). Addressing increasing interest in modeling evolution of small-world networks and scale-free networks Chen and Morris (Chen & Morris 2003) compared evolving visualizations of co-citation networks of scientific publications with two common link reduction algorithms, *minimum spanning trees* and *Pathfinder networks*, in respect to topological and dynamic properties. They concluded that in models of

minimum spanning trees high-degree nodes dominate the structure but high-order shortest paths suffer from significant links becoming removed whereas in models of Pathfinder networks cohesiveness of some of the most pivotal paths can be maintained thus offering more predictable and interpretable growth animation.

Müller et al (Müller et al. 2008) describe various perspectives that can be used to analyze wiki networks including social perspective (collaboration network, discussion network and message exchange network), knowledge perspective (competence network), information perspective (wiki-link network, author-link network and category network) and temporal perspective (information-flow network and visiting-flow network). Since a young child typically has a limited vocabulary that becomes gradually expanded we think that the growth process of knowledge of a child can have similarities with the characteristics of the temporal dynamic growing process of the Wikipedia and the static link-structures captured from any timeframe of the evolution history of the Wikipedia. Of course the Wikipedia represents a collectively produced average of individual work and thus does not have characteristics of an individually built knowledge structure and cannot necessarily address ideally requirements for a specific individual or her individual knowledge building process. On the other hand, the average nature of the knowledge structure of Wikipedia guarantees that when used by any random individual to support her knowledge building process there should be relatively high probability that her requirements overlap with the knowledge structure of the Wikipedia.

To provide useful support for an individual learner, we suggest to offer collective and diverse support instead of just a single examples and to invest some effort to find most suitable collaborators. For example, if a learner is just randomly coupled with any single co-learner or teacher there is a risk that too different mindsets and background knowledge—or too similar ones—prevent a fertile learning to happen. In addition, the question of limited resources is one important motivator to rely rather on collective than single support for learning. It is economically impossible to enable a private personal teacher for every individual learner. When aiming to find new ways to facilitate learning with automation, we think that it is useful to have some kind of collectively generated *collection of resources*. Without this kind of initial collectively built resource it seems to be difficult to develop suitable computational models and methods for social activities that have been used in traditional teaching. It also seems to be very laborious to develop a reliable automated process that can generate unique learning material for each individual learner from the scratch just based on the information about the learner. Thus to maintain sufficient efficiency in automation we suggest instead that a common collective resource that represents the needs of an average learner is used as a basis for generating learning material of each individual learner and it is tailored with sufficient modifications to address individual needs differing from average. We think that this approach to create automated support for learning that relies on collective basis also enables to make useful long-lasting modeling about learning processes, thus enabling comparative analysis about how the collective basis is tailored for each individual and enabling sustainable cumulative development of learning material.

In addition, it seems that somewhat *average nature* of various qualities seems to be the only type of knowledge structure a free collective process can easily produce. Thus even if a collective process can have hierarchical organizational features, we believe that its creative work cannot be kept well alive if controlled very strictly so it is important to enable and accept somewhat chaotic and average outcome resulting from collective work.

We suggest that there can exist parallel related processes of growing conceptual structures in both an individual human mind and as a collectively built Wikipedia encyclopedia. We do not claim that the *conceptual networks* in human mind and the hyperlink network are at all similar but anyway we want to emphasize that both structures have a somewhat limited number of individual concepts and they can be linked pair-wise with a somewhat limited number of links. Therefore even if there is a great difference in how the concepts in both collections are actually crosslinked, there are some shared general features relying on the aim to represent knowledge and understanding about principles of life with a limited set of cross-linked concepts. Motivated by this comparison, our work aims to open new perspectives to model human consciousness, thinking and planning with resources available from the Wikipedia. We think that learning processes can be possibly better understood and supported with the methodology that parallels conceptual structures of both human mind and the Wikipedia.

The collaboratively edited constantly growing Wikipedia online encyclopedia (<http://en.wikipedia.org>) currently contains over 4.3 million articles in English (as of June 2013). Each article defines a concept denoted by its title and the hyperlinks between articles define directed *conceptual relationships*. We think that enabling learners to explore hyperlink network of the Wikipedia pedagogically can provide sufficient coverage in core educational contents about many typical curriculum, especially in primary school and with challenged learners.

One promising domain to extract community generated tags for *ontology construction* is offered by the Wikipedia online encyclopedia. The Wikipedia provides an actively updated cross-linked network of articles and statements. For example article titles, article categories and hyperlink texts can be exploited as they were “tags” of a Wikipedia article (i.e. somewhat resembling tags used in social bookmarking). They indicate keywords or keyphrases describing a natural language concept represented by the corresponding article. It is computationally favourable that many of these tag-like features in Wikipedia articles obey hierarchically evolving abstraction and facilitate identification of the most essential semantic relations. For example, only a fraction of words in an article are hyperlinks and the hyperlinks in the beginning of an article provide often definitive relations whereas later hyperlinks provide more illustrative and detailed relations. In addition, the hyperlink distribution in both basic and advanced articles usually inherently supports rising the abstraction level in reasonable steps when accessing hyperlinks. The presence of this layered abstraction in the hyperlink network of the Wikipedia is a critical feature that favourably supports building a true ontology. According to (Strude & Ponzetto 2006), collaboratively created folksonomy extracted from the Wikipedia can be used in artificial intelligence and natural language processing

applications with the same effect as hand-crafted taxonomies or ontologies. They suggest computing semantic relatedness of concepts by retrieving corresponding Wikipedia articles and measuring their textual contents and paths in the category taxonomy.

Building both learning objects and intelligent tutoring systems has typically been laborious and become cost-effective only in a highly specified domain. We wanted to find new ontology-related solutions. Unfortunately, among many defined *learning content models*, only part of them supports standardized ontology-based content and metadata ((Verbert & Duval 2004); (Zouaq et al. 2007a)). Since manual generation of ontologies is slow and prone to errors, we considered automated or semi-automated methods as a necessity. We think that a community-driven approach, such as wiki environments including also the Wikipedia, can well support dynamic *collaboratively defined ontologies*. The Wikipedia does not have permanently fixed categorization of its content and the relations can sustain even radical changes to respond the changes in the average worldview. The content providers are asked to take care of updating the organization of the content as well. Since previous versions can be always reverted, it is safe to let the structure freely slowly converge towards a consensus while complementary contributions are gathered.

Despite uncertainties, the Wikipedia has been considered as a promising source for ontology construction ((Haase & Völker 2008); (Hu 2010)). Every Wikipedia article describes one concept denoted by the title of the article that has been considered having value for general public. Each hyperlink of this article literally shows a path to another related concept that has been collectively valued so much that a specific article has been written about it as well. Holloway et al. (Holloway et al. 2005/2007) suggest that they presented possibly the first *semantic map* of the English Wikipedia data.

We propose that browsing hyperlink structure of the Wikipedia can help learners in acquisition of new knowledge. In this sense, one earlier related work that is not based on the resources of the Wikipedia is a tool developed for expanding vocabulary of learners by collaboratively entering and reviewing unfamiliar words with an online database (Horst et al. 2005). Coursey et al. (Coursey et al.2008) argued that a combination of *keyword extraction* techniques combining graph-theoretical algorithms and methods relying on knowledge extracted from the Wikipedia can be successfully used to identify candidate keywords in learning objects. They suggest using ranking algorithm over the Wikipedia connectivity graph to find relevant articles. Somewhat similarly, our method exploits the titles of hyperlink's target articles to identify promising concepts in the Wikipedia. We introduce ranking that enables these concepts to be explored in learning paths, accompanied with compact relation statements parsed from the sentences surrounding each hyperlink.

The knowledge structure of the Wikipedia reflects the way humans as a community organize and relate things and concepts. We think that it is possible to make such interpretations that statistically the collective behaviour indicates about behaviour of individuals. It is possible to say that at least an average person (even if such average person in respect to all observed characteristics does not exist) would behave like the major trends in the Wikipedia indicate. We think that it is also possible to focus on

behaviour of representatives of a group that share same characteristics that can be measured and identified. Thus in our work we try to propose idea that the *collective activities* done by various alternative subgroups of people can offer way to model at least on coarse level even individual knowledge management and thinking processes of each individual belonging to those subgroups. We expect that by analysing the knowledge structures of the Wikipedia it can be possible to find significant statistical features and build models about individual knowledge processing and to support learning with these models once they have been implemented in computerized tools that fruitfully automate operation of the models in real educational life to support the needs of individual learners. With the assistance coming from these new advanced systems learners can also begin to assist each other with their complementing strengths and building learning material for future generations.

According to Janssen et al. (Janssen et al. 2008) a *learning path* describes a structure of actions a learner has to perform in order to attain a competence or a competence profile. In our proposal the learning paths can be represented with concept maps and other conceptual networks and educational exploitation of learning paths can be carried out by exploring diverse routings in these networks by chained traversing of links from concept to concept. In our research we are interested in methodology related to semantic navigation, intelligent tutoring systems and content-based filtering.

With swarm intelligence, spontaneous indirect coordination between agents can show optimal learning paths with a form of *self-organization* called stigmergy (Gutiérrez et al. 2006). Similarly, we think that automated generation of favourable learning paths can be effectively based on proceeding in the conceptual network represented by Wikipedia articles and inter-article hyperlinks.

2010a4d: Graph based visualizations relying on ontologies extracted from the Wikipedia have been proposed for education ((Dicheva & Dichev 2007); (Yang et al. 2007)). We now suggest extending the use of ontologies extracted from the Wikipedia to be applied in building personalized learning paths. This poses requirements to assess the quality of articles and perspectives that they can provide.

Supporting *knowledge acquisition* of a learner faces typical challenges of decision-making and creative problem solving. Due to complex dynamic nature of human learning, processes are hard to predict and evaluating solution candidates is costly. We think that educational methods can get useful influence from various domains, such as strategic planning, game theory and stochastic network models. Important results are that Muller games having winning condition relying on states visited infinitely often are optimally determined with *finite-memory strategies* (Dziembowski et al. 1997) and that winning conditions for parity games played on pushdown graphs can be realized also by *pushdown automata* (Walukiewicz 1996/2001). Some games, such as concave games and games with regret minimization, tend to converge to a *Nash equilibrium* ((Even-Dar et al. 2008); (Nadav & Piliouras 2010)).

Associations involving short time windows have been effectively modeled with *artificial neural networks* but for learning longer temporal relationships specific memory structures have been proposed (Starzyk & He 2009). With hidden Markov models Boyer et al. (Boyer et al. 2010) automatically extracted human tutoring modes

having significant correlations with student learning outcomes. Duran and Monereo (Duran & Monereo 2005) identified sequences of activities governing the exchanges present in peer tutoring of written composition task. Hou et al. (Hou et al. 2008) identified sequential patterns present in asynchronous discussions used for problem solving and knowledge construction.

To better understand underlying characteristics of the Wikipedia and how they could be fruitfully exploited to support learning we considered that it is important to evaluate the role of *vocabulary* as a mean for conveying information and building cumulative, chainable and crosslinked knowledge. In linguistics a term *lexicon* is commonly used to refer to vocabulary to highlight its contrasting role to *grammar*. We tried to get insight about the various ways to formulate knowledge and perspectives that can be taken to this knowledge by gathering few alternative complementing *high-frequency word lists*. Since childhood and adolescence constitute a period of life having a great rate of adoption of new knowledge and relating it to previous knowledge, we wanted to observe this gradual change in vocabulary. We think that it is possible to identify and define locally specific high-frequency word lists that summarize relatively reliably core factual content about certain knowledge entity.

Typically a high-frequency list about a text sample shows each distinct word occurring in this sample in descending order in respect to its frequency of occurrences. We think that high-frequency word lists can be successfully used as condensed representations to describe learning content on various levels of detail, such as describing for example the main themes of a full semester course, or more specific topic covered during a single one-hour lecture, or giving a compact definition in one phrase to answer student's question, or any other educational entity in addition to these examples. To address the *needs of the learner* when she becomes exposed to new knowledge and is expected to be able to fruitfully relate new knowledge to her prior knowledge we think that successful educational practices should take well into account the way she has conceptualised her previous knowledge and additionally her personal characteristics concerning age, gender, cultural and ethnic background, temperament, hobbies, interests and other features of personality. Therefore we suggest that high-frequency word lists can be a valuable way to model the learner's process of evolving conceptualization and adoption of new knowledge.

For us, it seemed natural to extend the idea of high-frequency word lists to *high-frequency link lists*. Thus we think that to summarize core factual content about certain knowledge entity even further, it is possible to identify and define most meaningful conceptual relationships (i.e. high frequency links) between a set of concepts (i.e. high-frequency words) describing that entity. To have increased value, these relationships could be supplied with a statement defining the nature of relationship.

As already mentioned above we have decided to focus in our further analysis only on those Wikipedia articles which are titled with a *common noun* (please note that in this dissertation with term "common noun" we specifically mean a noun that is typically written with a small initial letter and is opposite of a "proper noun", i.e. term "common noun" does not mean just any commonplace noun). Despite of some limitations coming from excluding from our analysis other Wikipedia articles than those dealing with

common nouns, it still seems fruitful in such respect that now analysis about linkage between articles can be considered to focus conveniently on verb based relationships between nouns. We think that this kind of semantically fixed perspective simplifies analysis and helps to guarantee that the results of analysis can be semantically reliable. For clarity reasons, it should be emphasized that later in this text when using a broader and less precise term high-frequency word list we are typically referring to a list containing only common nouns.

Even if we want ultimately to develop computational methods that can in very fine levels of detail adaptively support learning for any individual learner with her unique characteristics altogether, we think that with current incomplete understanding about possibilities of computational and psychological modeling it is practical to rely on methodology that somehow coarsely categorizes learners and learning content, and creates a mapping between the current features of the member belonging to a certain *category of learners* and recommendable next activities for her. We believe that one coarse way to categorize learners can be based on age of student so that for each annual age group a specific learning content is defined taking into account cumulative growth of knowledge so that new learning content requires that all previous learning content has been first sufficiently adopted. Besides categorization based on *age of student* we think that somewhat related categorization based on *language ability level* reach so far by student is very useful. We think that this current need for categorization and thus handling learners and learning content in bigger and somewhat discrete chunks can be seen as a similar kind of combination of advantage and challenge as developing learning content through collective process that averages the content. There is a need to find alternative and more advanced methodology to model and deal with learners and learning content but due to cost-efficiency for our current research we decided to accept the challenges of the classification and averaging with our current methodological approach.

3.8. Approaching learning with various levels of knowledge entities

Motivated by emergence of *small-world topology* in human brain networks (Wang et al. 2010) and in the Wikipedia (Ingawale et al. 2009) as well as indications about *scale-free properties* possibly in human brain networks ((Bullmore & Sporns 2009) referring to ((Eguíluz et al. 2005); (Van den Heuvel 2008); (Achard et al. 2006); (Bassett et al. 2006))) and more surely in the Wikipedia ((Zesch & Gurevych 2007); (Masucci et al. 2011)) we think that the knowledge structures represented in human mind have some analogues with information structures existing already currently in the Wikipedia online encyclopedia, and possibly also elsewhere in the World Wide Web (i.e. the Web) and its indexed web page collections. These emerging analogues give for us motivation to hypothesize that knowledge structures and processes of human mind can be relatively well mimiced even with just simple preliminary computational models. We suggest developing new computational models and tools to support education based on

structural correspondence between the knowledge represented by the Wikipedia and interlinked corpus used by humans.

It has been estimated that there are well over 54000 *word families* in English (Nation & Waring 1997). Furthermore, Kuhn and Stahl (Kuhn & Stahl 1998) mention based on previous research that people in school are exposed to 88700 different word families between kindergarten and grade 12 (Nagy & Andersson 1984) and that people learn about half of them which is about 45000 words or about 3000 word meanings per year ((Graves 1986); (White et al. 1990)). Lehr et al. (Lehr et al. 2004) mentions based on previous research that it has been estimated that there are 88500 distinct word families in school texts between grade 3 and grade 9 (Nagy & Andersson 1984). It has been suggested by Nation and Waring (Nation & Waring 1997) that a five-year-old child has a *vocabulary* of about 4000–5000 word families and then the vocabulary grows yearly with about 1000 word families for a native speaker until a university graduate has about 20000 word families. On the other hand, it has been estimated that a college student has a vocabulary of about 16785 words (D’anna et al. 1991). Hsu (Hsu 2009) has suggested that generally the proportion of words to word families is in range 1.54–2.18.

To create linguistic and semantic models with a systematic foundation, it has been considered useful to collect a collection of carefully balanced samples of varied texts and speech that form *corpora* (i.e. corpuses). Corpuses enable computing frequency lists of words and thus making assumptions of their relative significance. Even if it has been argued that semantic analysis should not give too much weight just for simple ranked word frequency lists we anyway think they can usefully facilitate prioritizing educational work. Before the emergence of facilitating computational resources an ambitious early work about word frequency lists has been presented by Thorndike (Thorndike 1921). One respected corpus of English language is *British National Corpus* (BNC) built in 1991–1994 consisting of about 100 million words with 90 percent based on texts and 10 percent on speech ((Leech et al. 2001); (British National Corpus XML edition 2007)). It was estimated that a subset of about 86 million words of British National Corpus (BNC), consisting of words that occur at least 100 times in BNC, contains 30297 different words or 14011 different lemmatized words (Chujo 2004).

We believe that learning can be fruitfully supported by developing computer-assisted methods for exploiting the Wikipedia as an educational resource and this belief is motivated by promising possibilities to model *learning process* by comparing and paralleling the building processes of knowledge structures in the Wikipedia and in the individual learner’s mind as well as in her learning community. Since *English language edition of the Wikipedia* (<http://en.wikipedia.org>) is clearly the biggest edition and suited for internationally communicated research, we have focused our analysis on English language edition of the Wikipedia but we expect that our proposals could be reasonably well applicable to other language editions as well. Since the foundation in 2001 the English version of the Wikipedia has grown to contain about 4.3 million articles as of June 2013 (Wikipedia statistics 2013), each article defining a concept corresponding to the article title, and thus together all these articles supplied with hyperlinks can be considered to form a crosslinked vocabulary of 4.3 million concepts.

For educational purposes *Simple English edition of the Wikipedia* (<http://simple.wikipedia.org/>) containing about 93000 articles as of June 2013 (Wikipedia statistics 2013) has an advantage that it is specifically tailored to represent knowledge content with simple vocabulary and grammar, and we think that it offers a useful resource, but since English language edition has much wider coverage our analysis focuses on English language edition. Anyway we think that along growth Simple English edition can offer increasing level of coverage and can be used fruitfully in parallel with English language edition to complement available perspectives to knowledge.

In 2001 it was estimated that the *World Wide Web* contained at least 550 billion documents, most of them in non-indexed part of the web (Bergman 2001), and that in January 2005 the indexed part of the Web contained 11.5 billion pages (Gulli & Signorini 2005). Fletcher (Fletcher 2012) reports referring to (Alpert & Hajaj 2008) that currently dominating search engine company Google had apparently identified one trillion distinct web addresses by year 2008 but it is estimated to have actually indexed about 40 billion web pages, and that several billion new web pages appear to World Wide Web daily. Fletcher (Fletcher 2012) argues that the Web offers extraordinary accessibility, quantity, variety and cost-effectiveness of machine-readable text for research about natural language processing, information retrieval and text mining.

The growth of *human knowledge* on population level has been accumulating along the recorded history and innovations in data storage, duplication, sharing and communication has helped to increase access and adoption of knowledge on individual level. It has been estimated that in 1993 only 3 percent of information in the world was stored in digital format, in 2000 the degree was 25 percent and in 2007 already 94 percent (Hilbert & López 2011). It has been estimated that during year 2003 the total amount of information stored on four major recording media (paper, plastic, optic and magnetic media) was 5608991 terabytes and flow of transmitted information (through television/radio, telecommunication and Internet) was 17876397 terabytes, and correspondingly during year 2008 stored information was 14716464 terabytes and information flow was 31327710 terabytes (Bounie & Gille 2012). If we assume that each 2 kilobytes of information corresponds to one typewritten page having thickness of 0.1 mm, the estimated amount of stored information in 2008 corresponds to about 7.36×10^{15} typewritten pages which means a stack of paper that is 736000000 kilometers high that could go 960 times from Earth to Moon and back.

A full collection of articles belonging to the English version of the Wikipedia can be represented in a downloadable format of about 10 gigabytes as of August 2013 (<http://dumps.wikimedia.org/enwiki/20130805>) and although this data size is relatively manageable for many commonly used computational devices it seems to us that identifying recommendable exploration paths for a student on the request based on computational analysis of article data typically leads to some delay due to heavy computation and thus is often balanced with pre-processing of the data or limiting analysis to a subset of all articles or to certain features of each article ((Mihalcea & Csomai 2007); (Milne & Witten 2008)).

The size of human vocabulary and the number of articles of the Wikipedia just discussed above can be contrasted with the neural structure of the *human brain* in which information is processed in a network consisting of neural cells called neurons. It has been estimated that a human brain contains about 86 billion neurons (Azevedo et al. 2009).

We have drawn together above mentioned values to Table 3.1 to enable approximated comparison between the size and coverage of various information sources thus letting to coarsely compare the growth of vocabulary of a human individual and the amount of articles in the English edition of the Wikipedia and the size of the World Wide Web. Please note that further observations about many suggested measures concerning learning are presented in Chapter 10. We here assume that each new *article* submitted to Wikipedia defines a *concept* denoted by its title and thus the descriptive article text as well as its hyperlinks to other articles (concepts) offer some kind of reasonable abstract resemblance to the process how a new concept is successfully understood and adopted into a human's vocabulary. To have an estimate about connectivity between concepts we have calculated the number of directed links L between N articles of Wikipedia English edition using relation $L=N^{1.4}$ mentioned by Zlatic et al. (Zlatic et al. 2006).

Due to encyclopedic characteristics of the Wikipedia the title of a Wikipedia article is typically represented in a form that resembles a noun, usually substantives, or at least a group of words that can be considered to sufficiently resemble noun. High dominance of nouns as the titles of the Wikipedia articles is fruitful for our aim to parallel knowledge structures of humans and the Wikipedia since Gentner and Boroditsky (Gentner & Boroditsky 2009) mention based on earlier research that there is a noun dominance in children's early word learning in both language production ((Gentner 1982); (Huttenlocher 1974); (Nelson 1973)) and comprehension (Goldin-Meadow et al. 1976).

We think that it is practical to emphasize in our further analysis especially those Wikipedia articles that describe a concept belonging to universally shared *everyday vocabulary* of language. Thus we have decided to focus on common nouns, and we have decided to avoid proper nouns (often dealing with organizations, locations, entertainment industry etc.) and various kinds of special pages and for example lists and category pages. Since the Wikipedia contains a lot of articles describing about other topics than common nouns we have supplied the Table 3.1 also with an estimate about the amount of Wikipedia articles having titles that can be considered as common nouns. We have generated this estimate based on a random sample of 1000 Wikipedia articles that turned out to have 138 titles considered as common nouns, thus suggesting that about 14 percent of Wikipedia articles describe a topic titled with a common noun. In the comparison shown in Table 3.1 it seems that when considering each Wikipedia article to represent a concept the English Wikipedia has greatly exceeded the average vocabulary of an educated adult.

However even if the Web and its subsections have some intellectually favourable features that are not yet fully understood and the future research hopefully can enable exploiting these features to support understanding human thinking, it needs to be

remembered that these features do not necessarily reveal the fundamental architecture of *semantic meaning* but merely reflect the design considered appropriate by the humans at the time of building these knowledge structures. So when studying for example knowledge structures of the Wikipedia we cannot expect to access fundamental results about how concepts are or should be organized in our universe but instead we can see how the current populations containing individuals with varying agendas build knowledge structures.

Table 3.1. Comparison of sizes of some information structures (further observations about many suggested measures concerning learning are presented in Chapter 10).

<i>Information structure</i>	<i>Number of units</i>
Human vocabulary (unique word families or words)	<i>5-year-old child:</i> 4000–5000 word families (Nation & Waring 1997); <i>adult:</i> 20000 word families (Nation & Waring 1997); 16785 words (D’anna et al. 1991); 45000 words ((Kuhn and Stahl 1998) referring to ((Graves 1986); (White et al. 1990))); proportion of words to word families in range 1.54–2.18 (Hsu 2009)
Words occurring at least 100 times in British National Corpus (based on a subset of about 86 million words)	30297 different words and 14011 different lemmatized words (Chujo 2004)
Word families in English	Well over 54000 (Nation & Waring 1997)
Word families student can encounter in school texts	88700 words families between kindergarten and grade 12 ((Kuhn & Stahl 1998) referring to (Nagy & Andersson 1984)); 88500 word families between grade 3 and grade 9 ((Lehr et al. 2004) referring to (Nagy & Andersson 1984))
Articles and hyperlinks in the English edition of the Wikipedia as of June 2013	4300000 articles (Wikipedia statistics 2013); 1900000000 hyperlinks (based on estimated formula (number of articles) ^{1.4} (Zlatic et al. 2006)); 590000 articles about common nouns (based on an estimated formula $0.138 \times (\text{number of articles})$ as explained in main text of Subchapter 3.8 by the author)
Indexed Web pages of the World Wide Web in 2008	40000000000 ((Fletcher 2011); (Google 2008))
Identified Web addresses in 2008	100000000000 ((Fletcher 2011); (Google 2008))
Information stored on four major recording media (paper, plastic, optic and magnetic media) in 2008	14716464 terabytes (Bounie & Gille 2012) corresponding to about 7.36×10^{15} typewritten pages
Neurons in a human brain	86000000000 (Azevedo et al. 2009)

Therefore research about semantics in the Wikipedia has strong flavor of research of sociology and anthropology, and we can hope that progressively research efforts done on wide scale of domains of research will make conceptual and semantical models more accurate even if it may never become possible for our species to fully understand the

intelligence implemented in our neural system. Anyway research about human mind seems to be a fascinating domain of research since it means that after extremely long evolution of life one of its species is actively trying to understand its own mental processes and the characteristics that have actually enabled this species to gain its dominant position on the Earth. Research trying to model human knowledge actually aims to solve the mysteries that govern the most fundamental processes of the evolution and reasons of life itself and its meaning.

3.9. Sample high-frequency word lists and conceptual relationships for students

To develop new computational and educational models relying on high-frequency word lists and high-frequency link lists, we gathered a set of *high-frequency words* that are typical for a student and her conceptualization about vocabulary dealing with her everyday life and her personal perspective towards it. Along the growing age and maturity of student the collection of high-frequency words can be expected to progressively change to handle more and more abstract and complex meanings. We think that there is need to identify high-frequency words for several consecutive levels of age and maturity of student, and especially in early life (about years 0–25) that offers dramatic expansion of knowledge to an individual human.

Word frequency effect has been noted so that people respond more quickly to high-frequency words of a language than low-frequency words of a language in respect to for example lexical decision, reading aloud, semantic categorization and picture naming (Duyck et al. 2008). To model human learning mechanisms, measuring word identification latency has been useful often carried out with lexical decision tasks (person decides if a shown letter string is a real word) or naming tasks (person names aloud a presented word) and can be motivated by word frequency, like in serial-search rank frequency models, threshold activation models and connectionist models, and contextual diversity (Jones & Jones 2008).

Age of acquisition effect has been identified both in native language acquisition and secondary language acquisition meaning that words learned earlier in a person's life can be recognized and produced more quickly than words learned later in life and it has been suggested that mappings between orthographic, phonological and semantic representations of words form a network that supporting later reconfigurations for new associations but still favouring connections learned early in language acquisition ((Izura & Ellis 2002); (Ellis & Lambon 2000)).

An interesting phenomena related to suggested *peaking of learning potential* during early years of life is experience of acceleration of passing of time along maturing of an individual and this has been explained so that apparent length of year is inversely proportional to a person's actual age (Morrison 1991) and one suggested formula to calculate one's effective age EA based on actual age t is $EA=80 \times \ln(t+1)/\ln(81)$ motivated with integral analysis of $\int_0^t \delta/(t+\epsilon) dt$ with conditions $t=0: EA=0$ and $t=80: EA=80$ (Pi 2001). Anyway we believe in life-long learning and that everyone has

important unique abilities that deserve appreciation and learning potential can be greatly supported with positive attitude and encouraging environment.

In our research we decided to emphasize analysis on *teenaged students* but we believe that our findings and modeling that we make with this age group can to some extent apply for students in other age groups as well. One of the reasons to emphasize teenaged students was that we expected that in our experiments it was more easy to reliably convey the goals of our educationally motivated empirical tasks to relatively mature students than younger students (or younger children) and then to evaluate and model more reliably their learning processes.

To gather a set of high-frequency words for teenaged students we carried out an *experiment* with a group of 103 students having ages ranging from 15 to 18 years and having learning abilities that can be considered normal. These students represented relatively diverse cultural backgrounds and school performance and some of them used in our experiment English language besides Finnish language but majority used Finnish language. In this experiment we asked each student to freely associatively write a list of 20 most important concepts (only common nouns) concerning topic “life” (it was ordered that the concept “life” itself should not be mentioned in the list). Then we asked everyone to review his generated list and give each concept a ranking values ranging from 1 to 20 (value 1 meaning the most important). Then we asked each student to draw a concept map by adding in a free ordering all the concepts to a paper and connecting with a non-directional line the most important connections between these concepts according to her intuition (thus linking direction was not specified when defining relationships between a pair of concept). Based on all of these concept maps we were able to generate *high-frequency word lists* and *high-frequency link lists* representing an approximated average conceptualization of knowledge of these students. Naturally, there are many alternative ways to define rankings for words and links.

We think that high-frequency word lists and high-frequency link lists enable us to define a conceptual frame for the *knowledge structure* typically held by a teenaged student and that helps to position the requirements for setting the learning goals that could rely on exploiting the large conceptual knowledge available in the Wikipedia in a fruitful way. We expect that every group of students will naturally generate somewhat different average high-frequency word lists and average high-frequency link lists. Especially we expect that along the learning process and maturing of student these lists can be seen evolving and possibly there are some shared trends of evolution and possibly these lists reach towards a conceptualization that can be considered to be somewhat a consensus of grown-ups about viewpoint on life. However we expect that in accordance with idea of life-long learning the evolution of these lists remain active through an individual’s whole life enabling her always to excel herself further.

In two tables, Table 3.2 and Table 3.3, is shown a sample of the highest-ranking common nouns (or other sufficiently resembling groups of words that according to us can be considered as common nouns) from some alternative ranking-driven word lists and lists of Wikipedia articles based on previous research and empirical data that we have gathered experimentally. If original word lists include other part-of-speech (or other Wikipedia pages) than those that we considered as common nouns we have

supplied each concept in both Table 3.2 and Table 3.3 with a ranking value indicating the ranking position of current concept among all part-of-speech (or all Wikipedia pages).

Table 3.2. A few most frequently used common nouns in writing and speech by children attending school level “preparatory” and children attending school level “year 4” (meaning fifth school level) based on Oxford Wordlist, highest-ranking common nouns gathered in current research from teenaged students with ranking based on occurrences in word lists generated by students and based on sums of measures of importance given by each student, and a few most frequent common nouns in British National Corpus.

Oxford Wordlist (school level Preparatory) (Lo Bianco et al. 2008)	Oxford Wordlist (school level Year 4) (Bayetto 2010)	Word lists of teenaged students (n=103) based on occurrence (Appendix P) (* = several concepts, due to space constraints shown in Appendix P)		Word lists of teenaged students (n=103) based on sum of measures of importance (Appendix Q)		Lemmatized words in British National Corpus (Kilgarriff 1997)	
		concept (ranking)	number of occurrences	concept (ranking)	sum of measures of importance	concept (ranking among all part-of-speech)	number of occurrences
concept (15)		family (1)	53	family (1)	903	time (53)	183427
weekend (21)	day (31)	friend (2)	49	friend (2)	821	year (60)	163930
dad (27)	mum (40)	work (3)	41	love (3)	525	people (80)	125430
home (28)	time (46)	death (4)	40	work (4)	445	way (89)	112636
house (29)	home (50)	love; school (5.5s)	33	water (5)	408	man (101)	97985
mum (32)	house (55)	food; water (7.5s)	31	food (6)	396	day (104)	92699
time (34)	going (58)	animal (9)	29	death (7)	363	thing (115)	77612
day (40)	school (63)	human (10)	24	school (8)	362	child (121)	71008
play (46)	dad (66)	birth (11)	23	human (9)	335	government (133)	66894
park (47)	can (80)	nature (12)	21	birth (10)	321	part (135)	65773
birthday (48)	people (81)	home (13)	18	nature (11)	303	life (137)	64423
Saturday (52)	will (82)	child; joy; sun (15s)	16	animal (12)	285	case (140)	63577
party (54)	friends (93)	dog; hobby; house (18s)	15	home (13)	237	woman (141)	63087
Sunday (55)	name (96)	education; health; money; sorrow; study (22s)	14	health (14)	225	work (146)	62248
dog (60)	night (100)	computer (25)	13	sun (15)	224	system (149)	61912
brother (69)	bed (104)	plant (26)	12	child (16)	202	group (155)	60689
football (71)	girl (111)	car; happiness; tree (28s)	11	joy (17)	195	number (156)	60607
friends (72)	door (113)	book; cat (30.5s)	10	hobby (18)	188	world (161)	59094
can (74)	play (119)	air; clock; learning; mother; summer; television (34.5s)	9	study (19)	186	area (162)	58449
love (76)	look (124)	living; music; party; religion (39.5s)	8	happiness (20)	179	course (164)	57776
zoo (79)	morning (126)	*	7	education (21)	172	company (165)	57754
school (86)	thought (134)	*	6	house (22)	147	problem (168)	56483
playing (88)	dog (136)	*	5	plant (23)	136	service (173)	54468
night (89)	car (138)	*	4	mother (24)	133	hand (176)	53265
bed (90)	way (140)	*	3	money (25)	130	party (177)	52979
shop (92)	game (147)	*	2	air (26)	121	school (181)	52227
bike (93)	water (153)	*	1	dog (27)	118	place (184)	51537
dinner (98)	room (154)			world (28)	106	point (190)	49187
car (99)	black (157)			father; living (29.5s)	105	house (191)	49022
fish (101)	family (158)			sorrow (31)	104	country (193)	48177
beach (105)	brother (160)					week (196)	47512
sister (105)							

In Table 3.2 as well as often in further analysis presented in this publication, if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is an average of all ranking values that would have been used if there were not need for sharing the position, and then again corresponding number of ranking values are skipped. We use suffix “-s” after the ranking value to indicate that it is a shared ranking value. For example frequencies 100, 90, 90, 80 and 70 would generate corresponding ranking positions 1, 2.5s, 2.5s, 4 and 5 (here 2.5 is motivated by calculation $(2+3)/2=2.5$). We decided to use this average ranking value approach since having lots of shared ranking positions makes distributions of ranking positions in parallel ranking listings to differ so much that comparison becomes difficult, and also when using statistical comparison tests this average ranking value approach is beneficial. Like for all decimal values in English text of this dissertation the decimal mark is indicated with a dot (not a comma).

The first and second column of Table 3.2 show based on *Oxford Wordlist* a few most frequently used common nouns in writing and speech by children attending school level Preparatory (Lo Bianco et al. 2008), based on 1891 writing samples, and children attending school level Year 4 (Bayetto 2010), based on 1251 writing samples, here school levels labeled somewhat confusingly since level Year 4 means the fifth school level. We did not have access to any part-of-speech classification concerning Oxford Wordlist and thus we self selected based on our own intuition which concepts we considered as common nouns in our further analysis and to be included in Table 3.2. In addition we did not have access to complete frequency values of Oxford Wordlist and thus we cannot use them in our further analysis and cannot provide them in Table 3.2. Furthermore, ranking values are given here in a consecutive manner even if some concepts of Oxford Wordlist may share same frequency value and thus also same ranking position which seems possible due to sequentially emerging alphabetical ordering in Oxford Wordlist.

The third and fourth column of Table 3.2 show highest-ranking words (only common nouns) we gathered in our experiment from teenaged students when they were asked to list and rank most significant vocabulary of 20 nouns concerning topic “life”. The third column shows high-frequency words (only common nouns) with ranking based on occurrences in word lists generated by students (each student could mention each concept at most once in her word list), full listing is available in Appendix P. The fourth column shows high-frequency words (only common nouns) with ranking based on sums of measures of importance originating from ranking given by each student for the words she generated to form her word list (ranking values originally given by students in ascending range from 1 to 20 were translated to an inverse descending range of measures of importance from 21 to 1, thus greater value now indicating more important), full listing is available in Appendix Q. For both third and fourth column the following rule applies: if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position, and for each concept at most one occurrence is counted per student.

Table 3.3 part 1 of 2 (starts here and continues on next page). Some of the highest-ranking Wikipedia articles having a title corresponding to a common noun in respect to trying to represent the most viewed article, the most edited article, the longest article in respect to file size and the most referenced article in respect to receiving links from other articles.

Most viewed articles in 2008 based on 210 analyzed days (Wikistics Falsikon 2009)		Most edited articles as of 30 July 2011 at 22:56 UTC (Wikipedia's pages with most revisions 2011)		Longest articles based on file size as of 29 July 2013 at 17:25 UTC (Wikipedia's long pages 2013)		Most referenced articles based on incoming internal links from articles (Wikipedia's most referenced articles 2011)	
article (ranking among all pages)	number of views (page hits) per day	article (ranking among all pages)	number of edits (revisions)	article (ranking among all pages)	file size in bytes	article (ranking among all pages)	sum of direct links and links via redirects arriving from other articles
wiki (5)	140550	World War II (118)	21552	Plasmodium falciparum biology (9)	369920	geographic coordinate system (1)	662158
sex (17)	40141	Catholic Church (124)	21163	2000s (decade) (17)	325203	International Standard Book Number (3)	272923
2008 Summer Olympic Games (22)	28627	2006 Lebanon War (143)	19256	Golden Eagle (20)	314623	music genre (5)	191980
World War II (39)	21020	global warming (151)	18636	impalement (30)	304675	time zone (6)	190736
vagina (40)	20634	Jehova's Witnesses (159)	17994	British literature (49)	280880	biological classification (7)	186918
penis (44)	19773	European Union (172)	17180	Iran-Iraq War (63)	268135	record label (9)	180716
masturbation (55)	18189	Islam (174)	17107	plug-in electric vehicle (68)	266102	animal (15)	138365
global warming (59)	17577	Christianity (183)	16575	Gaza War (71)	265224	association football (17)	125106
anal sex (63)	17327	Hurricane Katrina (188)	16490	Euro zone crisis (79)	262361	binomial nomenclature (18)	124074
love (64)	17297	anarchism (204)	15905	sexuality in ancient Rome (80)	262267	record producer (20)	110761
sexual intercourse (65)	17190	September 11 attacks (207)	15851	Roman Empire (87)	261014	World War II (21)	109653
World War I (66)	17033	Iraq War (250)	14308	history of Western civilization (92)	258988	daylight saving time (22)	106392
Halloween (69)	16890	Scientology (253)	14261	War in Afghanistan (2001-present) (106)	254038	digital object identifier (27)	86406
pornography (79)	15776	Gaza War (256)	14221	Catholic Church and Nazi Germany (107)	253978	village (30)	77282
Olympic Games (80)	15751	World War I (267)	13988	Genie (feral child) (111)	252703	English language (31)	77087

Table 3.3 part 2 of 2 (started on previous page and continues here).

Most viewed articles in 2008 based on 210 analyzed days (Wikistics Falsikon 2009)		Most edited articles as of 30 July 2011 at 22:56 UTC (Wikipedia's pages with most revisions 2011)		Longest articles based on file size as of 29 July 2013 at 17:25 UTC (Wikipedia's long pages 2013)		Most referenced articles based on incoming internal links from articles (Wikipedia's most referenced articles 2011)	
article (ranking among all pages)	number of views (page hits) per day	article (ranking among all pages)	number of edits (revisions)	article (ranking among all pages)	file size in bytes	article (ranking among all pages)	sum of direct links and links via redirects arriving from other articles
Thanksgiving (88)	15368	cannabis (drug) (270)	13959	Russia-Georgia War (122)	249273	studio album (32)	76866
canine reproduction (92)	15092	Buddhism (291)	13442	international reaction to the Gaza War (155)	244210	county seat (36)	67442
2012 (104)	13747	evolution (304)	13256	Holocaust (162)	243428	unincorporated area (37)	67146
September 11, 2001 attacks (106)	13686	2007 (305)	13251	international reactions to the Libyan civil war (167)	241623	UTC+02:00 (38)	67013
oral sex (107)	13681	2008 (326)	12817	Syrian civil war (172)	240847	UTC+01:00 (47)	57675
Great Depression (115)	13258	Vietnam War (356)	12277	beta distribution (191)	236930	arthropod (48)	57235
2008 (121)	12815	The Holocaust (369)	12129	flight and expulsion of Germans (1944–50) (192)	235912	single (music) (49)	57103
orgasm (131)	12326	Intelligent design (371)	12114	Honorific nicknames in popular music (194)	235427	Central European Time (53)	54388
Valentine's Day (132)	12279	cat (372)	12106	Iraq War (202)	234211	insect (54)	54317
Europe (141)	11917	Hinduism (373)	12087	International Space Station (207)	232789	World War I (55)	53497
Christmas (142)	11853	Atheism (388)	11970	Srebrenica massacre (213)	231525	mayor (56)	53159
Internet (152)	11456	Virginia Tech massacre (390)	11926	Miscegenation (221)	230182	chordate (57)	52540
socialism (161)	11145	9/11 conspiracy theories (397)	11810	Suez crisis (224)	229661	Catholic Church (58)	52531
Seven Wonders of the World (164)	11061	Fascism (399)	11771	humanitarian response by national governments to the 2010 Haiti earthquake (226)	229380	defamation (59)	52291
Vietnam War (165)	11032	2008 South Ossetia War (422)	11540	Romance languages (240)	227523	city (60)	52081

The fifth column of Table 3.2 shows a few most frequently occurring common nouns in British National Corpus (BNC) containing 100 million words of samples of English language of which 90 percent is based on texts and 10 percent based on speech (Kilgarriff 1997).

When comparing all five columns of Table 3.2 it seems that rankings based on vocabulary of children, vocabulary of teenagers and vocabulary of general language in BNC (and thus somewhat indirectly emphasizing vocabulary of adults) have important complementing alternative perspectives and foci (i.e. focuses) on language and conceptualization of phenomenon of everyday life. Observing this gradual change in emphasis of word rankings in consecutive age groups seems to support our idea of assisting student's learning with adaptive high-frequency word lists that can progressively introduce new concepts.

In Table 3.3 four first columns show some of the highest-ranking articles having a title corresponding to a common noun from the Wikipedia in respect to trying to represent the most viewed article (Wikistics Falsikon 2009), the most edited article (Wikipedia's pages with most revisions 2011), the longest article in respect to file size (Wikipedia's long pages 2013) and the most referenced article in respect to receiving links from other articles (Wikipedia's most referenced articles 2011), in one frozen timeframe. Fifth column shows some of the highest-ranking common nouns of lemmatized word list of British National Corpus (Kilgarriff 1997).

A principal criterion when we selected articles considered as common nouns was to exclude all articles titled with a person's name or country-level geographical or administrative topics as well as organizational and commercial names. These four rankings of Wikipedia articles highlight how greatly varied perspectives are available to large knowledge content stored in the Wikipedia and that there is a lot of unleashed potential for developing adaptive methods for pedagogic exploration of articles of the Wikipedia but careful planning is needed to manage to develop methods that can guarantee educationally motivated quality in exploration.¹¹ Even if many high-ranking articles deal with a topic that some people can consider as intimidating or taboo (for example articles about sexuality and wars) we think that indeed the great interest in these topics according to the high-ranking position in article listings of Table 3.3 tells clearly that existence of these articles is very meaningful and publication and availability of their information is welcome and can help to reduce irrational and harmful superstition, prejudice and conflicts as well as to support healthy living, freedom of speech, peace and democracy.

¹¹ Some additional high-ranking lists about evolution of the Wikipedia that can be used to identify *trends about topics* that are considered interesting for the users can be retrieved from lists that are listed in a list of lists of popular pages by WikiProject (http://en.wikipedia.org/wiki/Wikipedia:Lists_of_popular_pages_by_WikiProject), including for example a list of popular vital articles (http://en.wikipedia.org/wiki/Wikipedia:Vital_articles/Popular_pages) and a list showing most popular 25 articles weekly (<http://en.wikipedia.org/wiki/Wikipedia:5000/Top25Report>). Furthermore, interesting lists for emerging trends are a list trying to represent the most wanted articles (http://en.wikipedia.org/wiki/Wikipedia:Most_wanted_articles) and a list trying to represent the shortest articles (<http://en.wikipedia.org/wiki/Special:ShortPages>).

Naturally each high-ranking list shown in Table 3.3 shows just one frozen timeframe in constant evolution of the Wikipedia and due to the practice allowing anyone to freely edit articles we think that any kind of high-ranking lists describing evolution of the Wikipedia are fundamentally vulnerable to vandalism and manipulation and thus they should be analyzed critically when trying to develop models about collaborative editing and reading practices.

Anyway, despite the fact that several ranking lists shown in Table 3.2 and Table 3.3 have varying origins, we think that comparing all these ranking lists can reasonably well offer an overview and insight to the emerging challenge of our research that tries to find educational methods addressing various alternative ways to conceptualize concepts of everyday life and to prioritize them in ranking based on diverse personal characteristics and viewpoint. Our aim is to find methods that enable supporting bridging the alternative conceptualizations so that new knowledge structures can be efficiently adopted and linked to the previous knowledge structures held by an individual learner.

Appendix E shows two alternatively computed high-frequency word lists of 110 highest-ranking common nouns of British National Corpus ((Kilgarriff 1997); (Leech et al. 2001)), relying on about 100 million word corpus, and similarly 110 highest-ranking common nouns of Corpus of Contemporary American English ((Davies & Gardner 2010); (Word frequency data from COCA 2013)), relying on about 400 million word corpus, that reveal together some variation in rankings of everyday vocabulary. We could not fully understand why in online frequency lists of Corpus of Contemporary American English some of the frequencies did not seem to systematically descend along the provided rank position but anyway we decided to use these lists for our analysis. Especially comparison between rankings of British and American corpus highlights how in different cultural contexts different perspectives become emphasized in vocabularies and this kind of perspective differences offer a potential resource for modeling new computer-assisted educational methods to support adoption of new knowledge. For each of three lists the nouns are shown in descending order of frequency of occurrences in corpus. The number value in parenthesis after the word indicates position in ranking of all word classes (i.e. including also other word classes besides nouns).

3.10. Formation of conceptual networks for educational activities

Naturally there are many alternative ways to form conceptual networks for educational activities. Since we are strongly interested in exploiting knowledge structures of the Wikipedia for educational activities we think it is important to aim to parallel knowledge structures of the Wikipedia with knowledge structures representing conceptualization of students. To have a both compact and sufficiently representative collection of concepts in our further analysis we decided to focus specifically on a subset of words belonging to high-frequency words we have gathered from group of 103 teenaged students (as explained in Subchapter 3.9). We decided to select a subset of

words with a requirement that each accepted word is mentioned in word lists of at least four different students (i.e. frequency of occurrences for each word in all word lists must be at least four) and each student could mention each concept at most once in her word list. We think that requiring at least four students to mention each selected word guarantees that selected word is collectively considered significant. When selecting from high-frequency words of teenaged students only those mentioned by at least four students we ended up having a subset of 102 concepts and in our further analysis we will refer to this specific subset of 102 concepts with a term *102 core concepts* (all of them belonging to word class of common nouns).

Table 3.4 extends observations shown in Table 3.2 in columns three, four and five. Table 3.4 provides a more detailed comparison about the rankings of 102 core concepts in three alternative perspectives, as explained in the following. In Table 3.4 in columns 1–3 all 102 core concepts are shown in descending order of ranking based on occurrences in word lists generated by teenaged students and this ranking is contrasted with two other rankings shown in columns 4–5 and in columns 6–9. In columns 4–5 ranking is based on sums of measures of importance (originating from ranking given by each teenaged student for the words she generated to form her word list) on scale from 21 to 1, greater value indicating more important. In columns 6–9 ranking is primarily based on occurrences in lemmatized word list of British National Corpus (BNC) containing 6318 words occurring more than 800 times in BNC (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>)) and secondarily based on occurrences in non-lemmatized word list of British National Corpus containing 208656 word items occurring more than 5 times in BNC (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/all.num.o5>)). In ranking based on British National Corpus, frequency values were not available for “elderness”, “freetime” and “physical_training” since these concepts were not found either in lemmatized word list or non-lemmatized word list of British National Corpus occurring more than five times and thus a shared ranking value of 100s was given to these three concepts.

For both of these two contrasting ranking listings (i.e. sums of measures of importance and occurrences in British National Corpus) it is indicated in parenthesis how many positions higher the current word is in ranking when compared to the same word’s ranking based on occurrences in word lists generated by teenaged students.

Table 3.4 shows 102 core concepts in column 1 accompanied in parenthesis with the nearest corresponding article titles we managed to identify in the Wikipedia online encyclopedia if the exactly same phrasing was not found matching. For clarity, Appendix F shows all 102 core concepts both in English and Finnish due to the fact that part of vocabulary experiments in our research was carried out in Finnish even if we report the results in English. In addition, listings in Appendix F highlights some decisions made about semantics of 102 core concepts to make translations coherent even if nuances are not directly visible in both languages in the same way.¹² Among 102

¹² Based on our experimentally gathered conceptual material from students we identified for each of 102 core concepts *one specific major meaning* that is then used in our further analysis. Since in English many concepts have often many alternative meanings we want to clarify here especially four meanings based on

core concepts, when students generated concepts having two alternative meanings, like in cases “ground/earth” and “pen/pencil”, we decided to select only one option to represent current concept and the choice was done so that we selected the option which was positioned higher in ranking of British National Corpus when comparing positions of these two options currently in question. Please note also that our analysis about vocabulary collections and their linkage mainly focuses on nouns so that even if in some of our word listings for example word “love” can be considered either as a noun or verb we typically refer to a noun form.

An origin of challenge for our further analysis aiming to compare parallel conceptual relationships in concept maps generated by students and the hyperlinks in the Wikipedia comes from the fact that in some cases there were not well matching Wikipedia article available for each concept among concept maps. One example is that concept “friend” used in concept maps had to be coupled with concept Friendship in the Wikipedia and a specific significance for this disparity comes from the fact that in concept maps concept Friend seems to have strong position whereas concept Friendship does not seem to have as strong position and it remains partially unsolvable how largely this difference is caused by the disparity and how largely by other reasons. Other examples of unfortunate disparity between concept maps and the Wikipedia include couplings of concepts “air” versus Atmosphere_of_Earth, “cloth” versus Clothing, “elderness” versus Old_age, “succeeding” versus Management, “nutriment” versus Diet_(nutrition), “physical_training” versus Physical_fitness and “young_(person)” versus Adolescence.

our experimental data: “dream” carries a specific meaning of an imagery during sleeping, and respectively “goal” means a result to achieve, “nutriment” means a source of nourishment and “young” means a young person. In addition “physical_training”, even if containing two words, was considered as a concept due to original one-word Finnish concept “liikunta”. 102 core concepts includes concept “sister” which did not have directly corresponding article in the Wikipedia but instead article Sibling which was then used in our further analysis even if 102 core concepts did not include concept “brother”.

Table 3.4 part 1 of 3 (starts here and continues on next page). 102 core concepts with ranking based on occurrences in wordlists of students, sums of measures of importance and occurrences in word lists of British National Corpus.

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgarriff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
family	53	1	903	1 (0)	42773	218	36	9 (-8)
friend (Friendship)	49	2	821	2 (0)	31927 (Friendship: 2353)	296 (Friendship: 3138)	75 (Friendship: 1552)	16 (-14)
work	41	3	445	4 (-1)	62248	146	14	4 (-1)
death	40	4	363	7 (-3)	22712	453	142	24 (-20)
love	33	5.5s	525	3 (+2.5s)	13921	741	288	44 (-38.5s)
school	33	5.5s	362	8 (-2.5s)	52227	181	26	7 (-1.5s)
food	31	7.5s	396	6 (+1.5s)	21044	488	161	27 (-19.5s)
water	31	7.5s	408	5 (+2.5s)	35767	261	57	13 (-5.5s)
animal	29	9	285	12 (-3)	15250	671	248	36 (-27)
human	24	10	335	9 (+1)	5612	1693	797	67 (-57)
birth	23	11	321	10 (+1)	5889	1615	753	65 (-54)
nature	21	12	303	11 (+1)	18223	570	201	32 (-20)
home	18	13	237	13 (0)	39850	235	40	10 (+3)
child	16	15s	202	16 (-1s)	71008	121	8	3 (+12s)
joy	16	15s	195	17 (-2s)	2740	2864	1401	78 (-63s)
sun	16	15s	224	15 (0s)	9558	1058	453	54 (-39s)
dog	15	18s	118	27 (-9s)	12406	823	336	45 (-27s)
hobby	15	18s	188	18 (0s)	906	5864	3021	91 (-73s)
house	15	18s	147	22 (-4s)	49022	191	29	8 (+10s)
education	14	22s	172	21 (+1s)	25987	386	113	19 (+3s)
health	14	22s	225	14 (+8s)	24527	405	123	20 (+2s)
money	14	22s	130	25 (-3s)	37892	247	50	11 (+11s)
sorrow	14	22s	104	31 (-9s)	536 (first) 683 (all)*	12603 (first)*	5579 (first)*	93 (-71s)
study	14	22s	186	19 (+3s)	32786	287	69	15 (+7s)
computer	13	25	99	33.5s (-8.5s)	16976	602	214	34 (-9)
plant	12	26	136	23 (+3)	14638	698	264	41 (-15)
car (Automobile)	11	28s	80	47.5s (-19.5s)	35295 (Automobile: 217 (first) 302 (all)*)	263 (Automobile: 23319 (first)*)	59 (Automobile: 10274 (first)*)	14 (+14s)
happiness	11	28s	179	20 (+8s)	1656	3988	2016	86 (-58s)
tree	11	28s	85	43s (-15s)	14692	695	262	40 (-12s)
book	10	30.5s	99	33.5s (-3s)	37675	252	54	12 (+18.5s)
cat	10	30.5s	59	70s (-39.5s)	5377	1758	833	68 (-37.5s)
air (Atmosphere_of_Earth)	9	34.5s	121	26 (+8.5s)	19046 (Atmosphere: 4902)	544 (Atmosphere: 1889)	189 (Atmosphere: 900)	30 (+4.5s)
clock	9	34.5s	98	35 (-0.5s)	3279	2533	1233	75 (-40.5s)
learning	9	34.5s	103	32 (+2.5s)	2040	3446	1721	82 (-47.5s)
mother	9	34.5s	133	24 (+10.5s)	27784	354	99	18 (+16.5s)
summer	9	34.5s	85	43s (-8.5s)	11563	876	361	46 (-11.5s)
television	9	34.5s	84	45.5s (-11s)	9603	1051	450	53 (-18.5s)

Table 3.4 part 2 of 3 (started on previous page and continues here and on next page).

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgarriff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
living	8	39.5s	105	29.5s (+10s)	1688	3937	1983	85 (-45.5s)
music	8	39.5s	91	38s (+1.5s)	15024	681	255	39 (+0.5s)
party	8	39.5s	87	40 (-0.5s)	52979	177	25	6 (+33.5s)
religion	8	39.5s	62	65.5s (-26s)	4798	1922	920	69 (-29.5s)
city	7	46.5s	52	79.5s (-33s)	21596	477	153	25 (+21.5s)
cloth (Clothing)	7	46.5s	95	36 (+10.5s)	2130 (Clothing: 1892)	3352 (Clothing: 3630)	1665 (Clothing: 1818)	81 (-34.5s)
elderness (Old age)	7	46.5s	60	68 (-21.5s)	X (Old age: N/A)	N/A (Old age: N/A)	N/A (Old age: N/A)	100s (-53.5s)
environment	7	46.5s	75	52 (-5.5s)	14403	717	276	42 (+4.5s)
father	7	46.5s	105	29.5s (+17s)	23216	436	132	22 (+24.5s)
freetime (Leisure)	7	46.5s	91	38s (+8.5s)	X (Leisure: 2866)	N/A (Leisure: 2781)	N/A (Leisure: 1361)	100s (-53.5s)
holiday	7	46.5s	91	38s (+8.5s)	9731	1031	438	51 (-4.5s)
light	7	46.5s	67	59.5s (-13s)	18853	553	194	31 (+15.5s)
pet	7	46.5s	64	63s (-16.5s)	1375	4543	2319	89 (-42.5s)
world	7	46.5s	106	28 (+18.5s)	59094	161	18	5 (+41.5s)
childhood	6	58s	76	50.5s (+7.5s)	2853	2789	1367	77 (-19s)
disease	6	58s	28	150s (-92s)	10736	940	389	49 (+9s)
emotion	6	58s	86	41 (+17s)	3418	2469	1196	74 (-16s)
experience	6	58s	66	61 (-3s)	22751	452	141	23 (+35s)
fun	6	58s	85	43s (+15s)	2976	2722	1332	76 (-18s)
ground	6	58s	74	53 (+5s)	21504	480	155	26 (+32s)
growing	6	58s	72	55 (+3s)	127 (first) 232 (all)*	33083 (first)*	14539 (first)*	96 (-38s)
hate (Hatred)	6	58s	30	144.5s (-86.5s)	236 (first) 568 (all)* (Hatred: 1076)	22083 (first)* (Hatred: 5299)	9758 (first)* (Hatred: 2703)	95 (-37s)
heart	6	58s	80	47.5s (+10.5s)	15242	672	249	37 (+21s)
paper	6	58s	32	133.5s (-75.5s)	23694	423	130	21 (+37s)
sea	6	58s	48	85 (-27s)	11430	887	364	48 (+10s)
shoe	6	58s	52	79.5s (-21.5s)	4746	1935	925	70 (-12s)
sport	6	58s	62	65.5s (-7.5s)	8698	1160	518	56 (+2s)
baby (Infant)	5	71.5s	73	54 (+17.5s)	11503 (Infant: 2547)	883 (Infant: 2981)	363 (Infant: 1463)	47 (+24.5s)
biology	5	71.5s	44	94.5s (-23s)	1029	5440	2783	90 (-18.5s)
eating	5	71.5s	69	58 (+13.5s)	503 (first) 1019 (all)*	13198 (first)*	5861 (first)*	94 (-22.5s)
flower	5	71.5s	47	87.5s (-16s)	7086	1366	629	60 (+11.5s)
forest	5	71.5s	59	70s (+1.5s)	6832	1419	658	61 (+10.5s)
god	5	71.5s	59	70s (+1.5s)	6297	1520	707	62 (+9.5s)
goodness	5	71.5s	70	57 (+14.5s)	1418	4447	2274	88 (-16.5s)
peace	5	71.5s	71	56 (+15.5s)	8847	1142	507	55 (+16.5s)
pen	5	71.5s	33	126.5s (-55s)	2374	3115	1541	80 (-8.5s)

Table 3.4 part 3 of 3 (started two pages earlier and continues here).

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgarriff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
philosophy	5	71.5s	52	79.5s (-8s)	3590	2387	1149	73 (-1.5s)
purpose	5	71.5s	84	45.5s (+26s)	15159	674	251	38 (+33.5s)
succeeding (Management)	5	71.5s	64	63s (+8.5s)	64 (first) 114 (all)* (Management: 21884)	50611 (first)* (Management: 470)	22087 (first)* (Management: 149)	97 (-25.5s)
war	5	71.5s	27	153s (-81.5s)	29722	331	89	17 (+54.5s)
young_(person) (Adolescence)	5	71.5s	30	144.5s (-73s)	47 (first) 62 (all)* (Adolescence: 408 (first) 440 (all)*)	60785 (first)* (Adolescence: 15312 (first)*)	26462 (first)* (Adolescence: 6794 (first)*)	98 (-26.5s)
bed	4	90.5s	44	94.5s (-4s)	17947	578	207	33 (+57.5s)
bread	4	90.5s	49	84 (+6.5s)	3780	2294	1100	72 (+18.5s)
chair	4	90.5s	10	418s (-327.5s)	9718	1034	440	52 (+38.5s)
dream_(sleeping)	4	90.5s	53	77 (+13.5s)	6050	1580	733	63 (+27.5s)
evolution	4	90.5s	37	107s (-16.5s)	2447	3059	1510	79 (+11.5s)
exam (Test_(assessment))	4	90.5s	30	144.5s (-54s)	1511 (Test: 15491)	4252 (Test: 161)	2163 (Test: 243)	87 (+3.5s)
future	4	90.5s	58	72 (+18.5s)	14174	730	282	43 (+47.5s)
goal_(to_achieve)	4	90.5s	64	63s (+27.5s)	10655	950	394	50 (+40.5s)
hospital	4	90.5s	38	104.5s (-14s)	16898	604	215	35 (+55.5s)
marriage	4	90.5s	51	82.5s (+8s)	8668	1164	521	57 (+33.5s)
nutriment (Diet_(nutrition))	4	90.5s	61	67 (+23.5s)	9 (first) 9 (all)* (Diet: 4201)	156638 (first)* (Diet: 2121)	69617 (first)* (Diet: 1017)	99 (-8.5s)
organism	4	90.5s	41	98.5s (-8s)	1809	3744	1897	84 (+6.5s)
oxygen	4	90.5s	79	49 (+41.5s)	1870	3662	1839	83 (+7.5s)
parent	4	90.5s	76	50.5s (+40s)	20060	515	176	28 (+62.5s)
people	4	90.5s	41	98.5s (-8s)	125430	80	3	2 (+88.5s)
phone (Telephone)	4	90.5s	47	87.5s (+3s)	7150 (Telephone: 7842)	1357 (Telephone: 1258)	621	59 (+31.5s)
physical_training (Physical_fitness)	4	90.5s	54	75.5s (+15.5s)	X (Fitness: 1499)	N/A (Fitness: 4278)	N/A (Fitness: 2178)	100s (-9.5s)
pleasure	4	90.5s	52	79.5s (+11s)	5853	1628	762	66 (+24.5s)
rain	4	90.5s	34	121.5s (-31s)	6012	1588	736	64 (+26.5s)
sadness	4	90.5s	32	133.5s (-43s)	769 (first) 795 (all)*	9743 (first)*	4283 (first)*	92 (-1.5s)
sister (Sibling)	4	90.5s	32	133.5s (-43s)	8592 (Sibling: 299 (first) 458 (all)*)	1180 (Sibling: 18796*)	531 (Sibling: 8325 (first)*)	58 (+32.5s)
teacher	4	90.5s	34	121.5s (-31s)	19744	523	180	29 (+61.5s)
time	4	90.5s	55	74 (+16.5s)	183427	53	1	1 (+89.5s)
travel	4	90.5s	67	59.5s (+31s)	4118	2158	1034	71 (+19.5s)

The three rankings shown in Table 3.4 represent three different frequency distributions that can be compared in various ways. To compare the three rankings shown in Table 3.4 we used *five statistical comparison tests* that can be flexibly used with various kinds of distributions: sign test of paired samples, bootstrap version of Kolmogorov-Smirnov two-sample test, Goodman-Kruskal gamma statistic, Spearman's rank correlation coefficient rho and Kendall's rank correlation coefficient tau. In computation of these tests some inaccuracies may have become introduced to results due to dealing with shared ranking values (i.e. rank ties). It has been suggested that Goodman-Kruskal gamma statistic manages well with data containing many shared ranking values. On the other hand, to make sign test of paired samples behave correctly tie differences (i.e. having shared ranking) and zero differences are excluded from analysis and then also the total number of paired samples is reduced respectively.

We used five just mentioned comparison tests in two different ways that focus either on actual frequency distributions or ranking values. We compared three rankings in respect to actual frequency distributions (shown in Table 3.4 in columns 2, 4 and 6) that these rankings represent by using two tests: sign test of paired samples and bootstrap version of Kolmogorov-Smirnov two-sample test. We compared three rankings in respect to ranking values (shown in Table 3.4 in columns 3, 5 and 9) that have been created based on these frequency distributions by using three tests: Goodman-Kruskal gamma statistic, Spearman's rank correlation coefficient rho and Kendall's rank correlation coefficient tau.

During comparisons in respect to three missing frequency values of British National Corpus, for each of concepts "elderness", "freetime" and "physical_training" we decided to use values of zero (i.e. for "elderness" 0; for "freetime" 0; and for "physical_training" 0).

Our computation relied on rankings shown in Table 3.4 in columns 3, 5 and 9, and among them rankings of columns 3 and 9 are already in a scale ranging from 1 to 102 and to enable better comparison we now transformed also rankings of column 5 into a scale ranging from 1 to 102. Thus in fact following comparisons do not compare original rankings concerning occurrences word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus but instead considering only 102 core concepts belonging to each of these three rankings and only when these rankings are observed in a shared scale of ranking values ranging from 1 to 102.

Sign test of paired samples relies on estimating the difference in medians between two distributions. *Kolmogorov-Smirnov two-sample test* relies estimating the supremum of set of distances between empirical distribution functions of two samples. Since traditional Kolmogorov-Smirnov two-sample test does not allow tie values (i.e. having shared ranking) we used bootstrap version of Kolmogorov-Smirnov two-sample test allowing tie values that relies on performing bootstraps based on Monte Carlo simulations and we used value 1000 as parameter of number of bootstraps to be performed since values of at least 500 or preferably 1000 have been suggested to reach suitable accuracy (Sekhon 2011).

Goodman-Kruskal gamma statistic, *Spearman's rank correlation coefficient* (i.e. Spearman's rho (ρ)) and *Kendall's rank correlation coefficient* (Kendall's tau (τ)) are non-parametric measures of statistical dependence between rankings of samples indicating the degree of correlation with values ranging from -1 (negative correlation) to 1 (positive correlation) so that value 0 represents absence of correlation.

We used each of five just mentioned comparison tests to check if a null hypothesis that corresponds each of these tests either becomes rejected or does not become rejected. Table 3.5 lists for each of the five tests a description about its null hypothesis supplied with notation that we used and we refer to this notation also in our further analysis.

Table 3.5. Five tests used to compare two samples in our research. A null hypothesis corresponding to each of five comparison tests is explained with notation and description.

Test comparing two samples	Null hypothesis	
<i>Name</i>	<i>Notation</i>	<i>Description</i>
sign test of paired samples	Hst	there is no difference in medians between two distributions represented by the two samples
bootstrap version of Kolmogorov-Smirnov two-sample test	Hks	both of the two samples represent the same distribution
Goodman-Kruskal gamma statistic	Hgk	gamma=0 thus meaning that there is absence of association between rankings of two samples
Spearman's rank correlation coefficient rho	Hsk	rho=0 thus meaning that there is absence of association between rankings of two samples
Kendall's rank correlation coefficient tau	Hkr	tau=0 thus meaning that there is absence of association between rankings of two samples

To facilitate identifying possible similarities between three frequency distributions of Table 3.4 we transformed frequency values into approximately same range of values thus forming scaled frequency distributions. We now next explain how this transformation was carried out. We empirically defined three weighting parameters that seemed to sufficiently successfully transform frequency values of each of three original distributions to three scaled distributions so that sign test of paired samples between each three pairs of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between each three pairs of these scaled frequency distributions is as small as possible.

Therefore we decided that scaled frequency distribution of occurrences in word lists has a weighting parameter 1 and scaled frequency distribution of sum of measures of importance a weighting parameter 0.085 and scaled frequency distribution of occurrences in British National Corpus a weighting parameter 0.00077. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution. Figure 3.1 shows three scaled frequency distributions, supplied with a curve $y=328/x$ that is a prediction based on Zipf's law (Zipf 1935) which claims that in large samples of natural language the frequency of any word $f(z)$ is inversely

proportional to its rank z based on the high-frequency list of all words (thus approximately $f(z) \sim 1/z$), and also parameter 328 in the formula of this curve $y=328/x$ is motivated by thus minimizing difference in medians between the values of this curve and occurrences in word lists generated by students. We used these scaled frequency distributions in our further analysis including Figure 3.1, Table 3.6 and Figure 3.2.

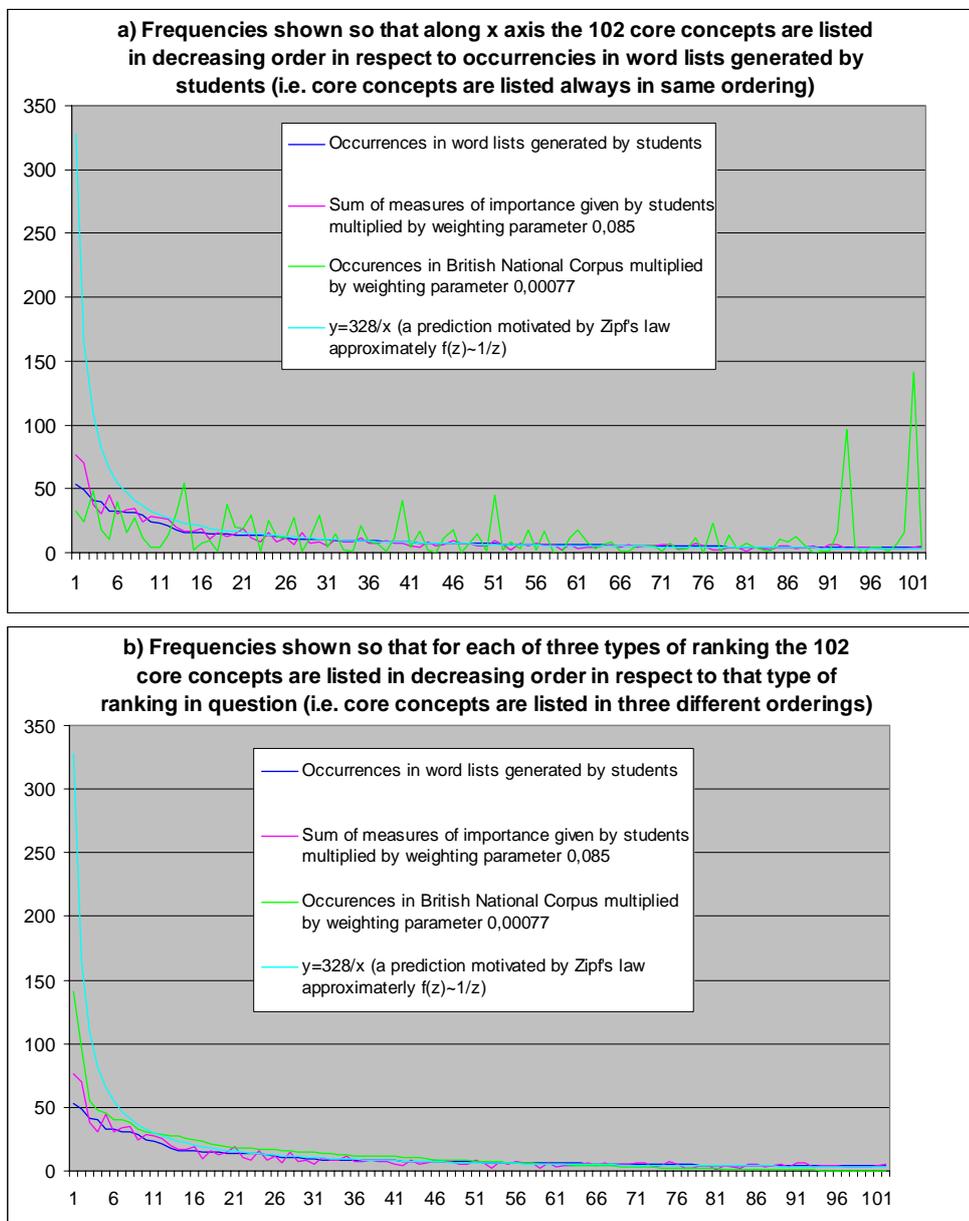


Figure 3.1. Scaled frequency distributions about rankings of occurrences in word lists of students, sum of measures of importance given by students and occurrences in British National Corpus so that core concepts are listed in same ordering thus frequencies not decreasing together (a) and in different ordering thus frequencies decreasing together (b). Ordering of core concepts in subfigure a is same as in first column of Table 3.4 (in decreasing order in respect to occurrences in word lists generated by students).

We carried out each of five comparison tests so that when comparing two samples we compared values that represented always the same concept (i.e. core concepts were always listed in same ordering in a similar way as shown in Figure 3.1 in subfigure a and not as in subfigure b, thus meaning in decreasing order in respect to occurrences in

word lists generated by students). For each of five comparison tests Table 3.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between three rankings concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus. Figure 3.2 visualizes correlations between three ranking values concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus.

Table 3.6. Degrees of dependency between three rankings concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
Distribution A	Distribution B	Sign test of paired samples	Bootstrap version of Kolmogorov-Smirnov two-sample test	Goodman-Kruskal gamma statistic	Spearman's rank correlation coefficient rho	Kendall's rank correlation coefficient tau
Occurrences in word lists generated by students (scaled)	Sum of measures of importance given by students (scaled)	$p=1$ (null hypothesis Hst not rejected)	$p=0.03962$ (null hypothesis Hks rejected)	gamma=0.7584478 (standard error 0.09718651); null hypothesis Hgk rejected ($p=5.995204 \times 10^{-15}$)	rho=0.8591361; null hypothesis Hsr rejected ($p < 2.2 \times 10^{-16}$)	tau=0.7158213; null hypothesis Hkr rejected ($p < 2.2 \times 10^{-16}$)
Occurrences in word lists generated by students (scaled)	Occurrences in British National Corpus (scaled)	$p=1$ (null hypothesis Hst not rejected)	$p=0.0002393$ (null hypothesis Hks rejected)	gamma=0.2785962 (standard error 0.1427654); null hypothesis not rejected ($p=0.0510064$)	rho=0.3661874; null hypothesis Hsr rejected ($p=0.0001537$)	tau=0.2637514; null hypothesis Hkr rejected ($p=0.0001723$)
Sum of measures of importance given by students (scaled)	Occurrences in British National Corpus (scaled)	$p=1$ (null hypothesis Hst not rejected)	$p=0.002647$ (null hypothesis Hks rejected)	gamma=0.2468701 (standard error 0.1368832); null hypothesis Hgk not rejected ($p=0.07130832$)	rho=0.3576171; null hypothesis Hsr rejected ($p=0.0002242$)	tau=0.2459333; null hypothesis Hkr rejected ($p=0.0002626$)

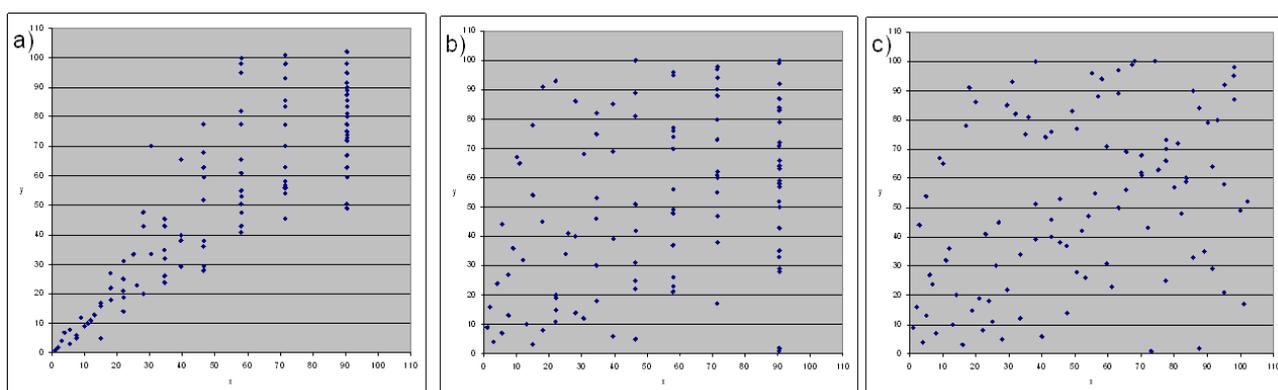


Figure 3.2. Visualization of three correlations: a) between ranking values of occurrences in word lists generated by students (x) ($n=103$) and ranking values of sum of measures of importance given by students (y) ($n=103$), b) ranking values of occurrences in word lists generated by students (x) ($n=103$) and ranking values of lemmatized word lists of British National Corpus (y), and c) ranking values of sum of measures of importance given by students (x) ($n=103$) and ranking values of lemmatized word lists of British National Corpus (y). To enable comparison, all ranking values are in scale ranging from 1 to 102 (thus differing from Table 3.4 the ranking values of sum of measures of importance given by students have now also been transformed into scale ranging from 1 to 102). Ordering of core concepts in all subfigures (a, b and c) is same as in first column of Table 3.4 (in decreasing order in respect to occurrences in word lists generated by students).

Based on comparison shown in Table 3.4, we have generated Table 3.7 showing the greatest and smallest ranking difference (distance of ranking positions) when comparing ranking based on sum of measures of importance (on scale 1–21, greater value indicating more important) given by each student for the words she generated to form her word list and ranking based on occurrences in word lists generated by students. To enable comparison, differing from Table 3.4 the ranking values of sum of measures of importance given by students have now also been transformed into scale ranging from 1 to 102.

Table 3.7. Some of the greatest and smallest ranking differences for concepts in respect to occurrences in word lists generated by students versus sum of measures of importance given by each student (n=103). Concepts having the greatest and smallest ranking difference when comparing ranking based on sum of measures of importance (on scale 1–21, greater value indicating more important) given by each student for the words she generated to form her word list and ranking based on occurrences in word lists generated by students. To enable comparison, differing from Table 3.4 the ranking values of sum of measure of importance given by students have now also been transformed into scale ranging from 1 to 102.

Some of the greatest ranking differences for concepts having higher ranking based on sum of measures of importance given by each student than based on occurrences in word lists generated by students		Some of the greatest ranking differences for concepts having lower ranking based on sum of measures of importance given by each student than based on occurrences in word lists generated by students		Some of the smallest ranking differences for concepts between ranking based on sum of measures of importance given by each student and based on occurrences in word lists generated by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
oxygen	41.5s	disease	-42s	family; friend; home	0
parent	40s	hate	-40s	hobby; sun	0s
travel	31s	cat	-39.5s	evolution	0.5s
goal_(to_achieve)	27.5s	paper	-37s	clock; party	-0.5s
purpose	26s	city	-31s	birth; human; nature	1
nutriment	23.5s	war	-29.5s	education	1s
future; world	18.5s	young_(person)	-26.5s	work	-1
baby; time	17.5s	religion	-26s	child; rain; teacher	-1s
emotion; father	17s	sea	-24s	food; forest; god; hospital; music	1.5s
		pen	-21.5s	joy	-2s
		elderness	-21.5s	learning; love; water	2.5s
				school	-2.5s

It appears that when contrasted with original frequency-based ranking of core concepts in word lists generated by students, the students on average gave higher sums of measures of importance to such concepts as “oxygen”, “parent”, “travel”, “goal_(to_achieve)” and “purpose”, and respectively lower sums of measures of importance to such concepts as “disease”, “hate”, “cat”, “paper”, “city”, “war” and “young_(person)”. The original frequency-based ranking of core concepts in word lists generated by students was followed closely by the levels of sums of measures of importance among such concepts as “family”, “friend”, “home”, “hobby” and “sun”. It

is interesting that three concepts having the highest occurrences in word lists generated by students (“family”, “friend” and “work”) belong to those concepts having some of the smallest ranking differences between ranking based on sum of measures of importance and based on occurrences in word lists, so we think that possibly there can be some partially subconscious processes that assist humans to position certain dominant concepts of everyday life often into same specific ranking positions even in varying contexts.

Similarly, based on comparison shown in Table 3.4, we have generated Table 3.8 showing the greatest and smallest ranking difference (distance of ranking positions) when comparing ranking based on occurrences in British National Corpus and ranking based on occurrences in word lists generated by students. It appears that when contrasted with original frequency-based ranking of core concepts in word lists generated by students, the frequency-based ranking in British National Corpus had a higher ranking for such concepts as “time”, “people”, “parent”, “teacher” and “bed”, and respectively a lower ranking to such concepts as “hobby”, “sorrow”, “joy”, “happiness” and “human”. The original frequency-based ranking of core concepts in word lists generated by students was followed closely by the frequency-based ranking in British National Corpus among such concepts as “music”, “work”, “philosophy”, “sadness” and “school”.

Table 3.8. Some of the greatest and smallest ranking differences for concepts in respect to occurrences in word lists generated by students (n=103) versus occurrences in British National Corpus. Concepts having the greatest and smallest ranking difference when comparing ranking based on occurrences in British National Corpus and ranking based on occurrences in word lists generated by students. Please note that concepts “elderness”, “freetime” and “physical_training” were not found either in lemmatized word list or non-lemmatized word list of British National Corpus occurring more than five times and thus a shared ranking value of 100s was given to these three concepts.

Some of the greatest ranking differences for concepts having higher ranking based on occurrences in British National Corpus than based on occurrences in word lists generated by students		Some of the greatest ranking differences for concepts having lower ranking based on occurrences in British National Corpus than based on occurrences in word lists generated by students		Some of the smallest ranking differences for concepts between ranking based on occurrences in British National Corpus and based on occurrences in word lists generated by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
time	+89.5s	hobby	-73s	music	+0.5s
people	+88.5s	sorrow	-71s	work	-1
parent	+62.5s	joy	-63s	philosophy; sadness; school	-1.5s
teacher	+61.5s	happiness	-58s	health; sport	+2s
bed	+57.5s	human	-57	home	+3
hospital	+55.5s	birth	-54	education	+3s
war	+54.5s	elderness; freetime	-53.5s	exam	+3.5s
future	+47.5s	learning	-47.5s	air; environment	+4.5s
world	+41.5s	living	-45.5s	holiday	-4.5s
goal_(to_achieve)	+40.5s	pet	-42.5s	water	-5.5s
				organism	+6.5s

It is interesting that four concepts related to topics in educational context (i.e. concepts “teacher”, “learning”, “school” and “education”) have different role in this comparison of rankings. Concept “teacher” has higher ranking in British National Corpus (suggested to emphasize vocabulary of adults), concept “learning” has a higher ranking in word lists generated by students (suggested to emphasize vocabulary of young people), and for both concept “school” and concept “education” rankings are close in British National Corpus and word lists generated by students (suggested to have relatively neutral balancing emphasis on vocabularies of adults and young people). We think that already this example of three complementing perspectives towards concepts related to topics in educational context give support for our proposal of exploiting diverse alternative rankings of concepts and conceptual relationships to explore conceptual networks in pedagogically rewarding way thus addressing adaptively the learner’s personal needs.

Table 3.9 shows the highest-ranking conceptual relationships among the concept maps generated by the students in the experiment. Since the students did not specify linking direction for the relationships, each pair of concepts is shown in alphabetical order. The relationships are listed in descending order of occurrences in concept maps.

As explained above, we first identified 102 concepts, called *102 core concepts*, that at least four students mentioned in her generated list of concepts (shown in Table 3.4). We then formed a list containing all conceptual relationships that the students had defined between these 102 core concepts in concept maps drawn by students. In this publication we use notation $\text{conceptA}\bowtie\text{conceptB}$ (i.e. two concepts separated with so called currency sign (\bowtie) having Unicode code U+00A4) to represent these relationships defined by students in concept maps since these relationship do not have any specified linking direction. We decided to take into further analysis a subset of this list so that it contains only such conceptual relationships that are mentioned by at least two students in concept maps. We expanded this subset to contain also those conceptual relationships—mentioned by at least two students in concept maps drawn by students—that had been defined between concept “brother” and 102 core concepts (this addition contained two relationships that are $\text{brother}\bowtie\text{family}$ and $\text{brother}\bowtie\text{friend}$). Motivation for connecting concept “brother” to 102 core concepts is that we planned to compare drawn concept maps to hyperlink structure of the Wikipedia and in the Wikipedia both entry Sister and entry Brother are redirected to shared Wikipedia article Sibling and thus in the Wikipedia concept Sibling represents both concepts Brother and Sister.

Table 3.9. 145 core relationships that are in fact all those relationships between 102 core concepts, extended with concept Brother, that are mentioned by at least two students in concept maps drawn by students (n=103), shown in descending order of occurrences in concept maps. Since relationships do not have any specified linking direction, each pair of concepts is shown in alphabetical order (concept A and concept B).

Conceptual relationship (linking direction not specified)			Conceptual relationship (linking direction not specified)			Conceptual relationship (linking direction not specified)		
Concept A	Concept B	Occurrences	Concept A	Concept B	Occurrences	Concept A	Concept B	Occurrences
family	friend	15	death	war	3	environment	family	2
birth	death	13	dog	family	3	environment	nature	2
family	love	13	dog	pet	3	experience	work	2
friend	school	10	education	school	3	family	health	2
family	home	9	family	house	3	family	hobby	2
school	work	9	family	joy	3	family	money	2
animal	nature	8	family	work	3	family	pet	2
friend	love	8	food	health	3	family	phone	2
child	family	7	food	living	3	family	study	2
death	living	7	freetime	hobby	3	father	home	2
family	father	7	friend	party	3	food	television	2
family	living	7	ground	water	3	freetime	friend	2
joy	sorrow	7	happiness	love	3	freetime	television	2
family	mother	6	hobby	school	3	friend	living	2
father	mother	6	home	house	3	friend	pet	2
food	water	6	home	school	3	friend	study	2
friend	hobby	6	home	work	3	friend	work	2
money	work	6	living	religion	3	friend	young_(person)	2
birth	living	5	living	school	3	god	organism	2
education	work	5	living	water	3	ground	nature	2
living	nature	5	nature	sun	3	health	light	2
nature	plant	5	school	study	3	health	physical_training	2
plant	tree	5	air	ground	2	heart	love	2
study	work	5	animal	environment	2	hobby	work	2
air	water	4	animal	god	2	holiday	party	2
animal	dog	4	animal	tree	2	holiday	work	2
cat	dog	4	birth	child	2	home	mother	2
computer	television	4	birth	family	2	house	work	2
death	disease	4	birth	growing	2	joy	living	2
death	health	4	birth	human	2	joy	love	2
family	happiness	4	birth	nature	2	learning	love	2
family	human	4	book	school	2	living	music	2
friend	happiness	4	brother	family	2	living	organism	2
friend	human	4	brother	friend	2	living	peace	2
friend	joy	4	car	family	2	living	purpose	2
human	living	4	car	house	2	living	sorrow	2
human	love	4	chair	house	2	living	sun	2
human	nature	4	child	hospital	2	living	travel	2
living	love	4	child	human	2	love	mother	2
living	work	4	clock	computer	2	love	nature	2
nature	water	4	clock	school	2	love	parent	2
animal	family	3	cloth	shoe	2	nature	tree	2
animal	food	3	computer	freetime	2	nutriment	water	2
animal	human	3	death	nature	2	oxygen	water	2
biology	nature	3	disease	health	2	school	teacher	2
birth	health	3	dream_(sleeping)	health	2	sea	water	2
death	elderness	3	education	living	2	summer	sun	2
death	human	3	elderness	health	2			
death	sorrow	3	emotion	love	2			
(the list continues in column 4)			(the list continues in column 7)					

Finally, we had managed to form a collection of altogether 145 conceptual relationships, called *145 core relationships*, aiming to represent knowledge structures of the students between 102 core concepts extended with concept “brother”. It turned out that in these 145 core relationships only 75 distinct concepts of 102 core concept are used (75 of 102 concepts if word “brother” can be seen representing word “sister” since it appears that concept “sister” is not inherently among those 75 distinct concepts although concept “sister” belongs to 102 core concepts). We think that relationships identified for concept “brother” can sufficiently represent relationships identified for concept “sister” when comparing concept maps and hyperlink structure of the Wikipedia especially when considering a broader conceptual context of term sibling (since, as just mentioned, in the Wikipedia concept Sibling represents both concepts Brother and Sister). Table 3.9 shows a listing of all 145 core relationships in descending order of occurrences in concept maps generated by teenaged students and since these relationships do not have any specified linking direction, each pair of concepts are shown in alphabetical order.

Figure 3.3 shows all 145 core relationships. Please note that in Figure 3.3 and in all other resembling figures of this publication the location of a concept in respect to other concepts and length of arcs or arrows connecting them does not have any specific indication about closeness or relatedness of these concepts. This means that concepts are placed to their location just based on human intuition with an aim to keep visualization of network of concepts as compact and clear as possible so that new connecting lines could be easily drawn from one concept to another concept so that other lines can still be easily distinguished from them.

In Figure 3.3 linking direction of a relationship between a pair of concepts was not specified in concept maps and thus only connecting lines are shown instead of arrows. Figure shows 73 concepts plus an additional concept brother. Concepts that do not have exactly same phrasing in the nearest corresponding article titles in the Wikipedia are supplied with an asterisk (*) and in addition concept brother is written in italics due to representing also related terms sister and Sibling. To facilitate comparison of this figure with analysis presented later in this dissertation two specific notations are made to this figure: concepts that are not mentioned in hyperlinks of the Wikipedia connecting 102 core concepts are written with purple font (see explanation in text just before Table 5.4) and concepts that have been unreachable in surfing experiment inside “hyperlink network of 55 concepts” starting from concept Human are written with turquoise font (see Table 5.19).

Figure 3.4 shows 41 highest-ranking hyperlinks of 145 core relationships (based on Table 3.9) so that greater width of the connecting lines indicates higher number of occurrences in concept maps drawn by students. Thus Figure 3.4 can be seen to show a highest-ranking subsection of the hyperlinks of Figure 3.3 and even supplied with line width indicating hierarchy among these hyperlinks in respect to number of occurrences in concept maps.

PART II. Collaborative building of link-based knowledge representations in learning

Chapter 4. Addressing complementing personal strengths in collaborative learning platform

In publication [P1] we proposed an *educational framework* (collaborative learning platform) and computational methodology for collaborative learning. In publication [P1] we define a new way to support creative collaborative work of building knowledge structures and coordination of collaborative activities to gain mutually agreed solutions in web environment based *Competing Values Framework* model that is motivated by long empirical studies carried out in organizational studies ((Quinn & Rohrbaugh 1983); (Belasen & Frank 2008)).

We now here first explain basic idea and motivation about Competing Values Framework model and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P1]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P1]. Figure 4.1 illustrates the main idea of the method proposed in publication [P1].

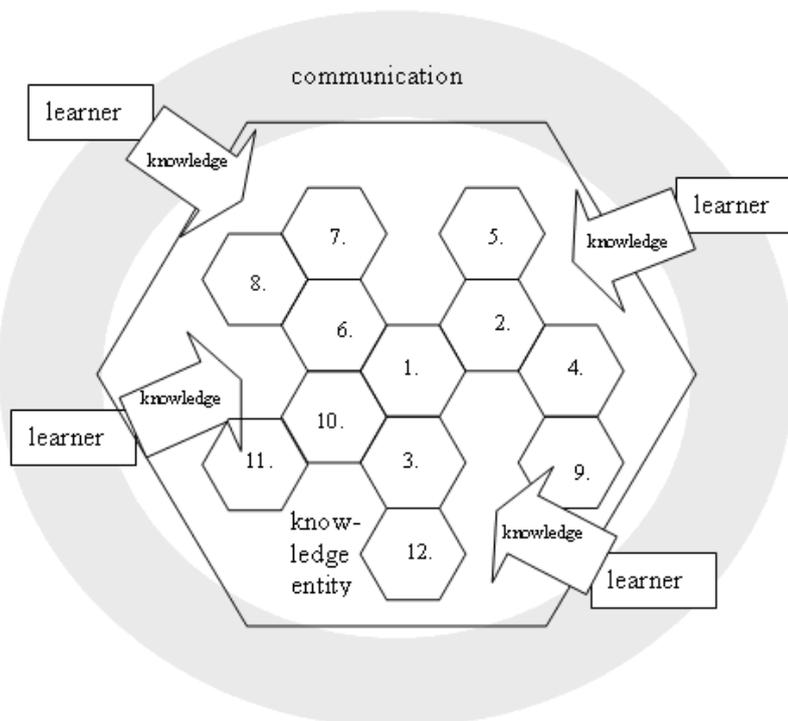


Figure 4.1. Main idea of the method proposed in publication [P1] for collaborative learning platform.

In Figure 4.1 the linked hexagons together represent a collectively generated and gradually built concept map by collaborating learners. Each hexagon represents a concept added or edited by one of the collaborators (corresponding to a node in concept map) and a shared edge between two hexagons indicate defined relationship between concepts (corresponding to an arc in concept map). The numbers indicate the order in which the concepts have been added to the concept map. Along collaborative knowledge construction process communication is carried out between all collaborators to agree about actions to be taken.

We do not know any previous research trying to apply Competing Values Framework in to educational setting in the proposed way. Please note that in the following text our educational framework (collaborative learning platform) will be referred to as a *platform* even if we consider it essentially to represent a framework since we want to avoid confusion with the model of Competing Values Framework. In publication [P1] we actively refer to our educational framework (collaborative learning platform) with terms collaborative ideation scheme and collaborative ideation platform.

4.1. Requirements for a collaborative learning platform

As explained in publication [P1] some aspects that we consider essential for a collaborative learning platform supporting computer-assisted learning include formation of a group, identification of a collaborator role for each participant, sharing responsibilities according to person's collaborator role and enabling rich textual dialogue with visualization. We considered that shared concept maps can be valuable for synthesizing and distributing collaborative work.

In publication [P1] we suggest building a system that monitors collaboration activities and if personal responsibilities of collaborators do not become fulfilled, the system should provide guidance messages to restore desired activity patterns. We suggest a methodology for collaborative learning platform in the context of supporting learning of conceptual structures collaboratively. Collaborating learners are expected to expand their conceptualization while they relatively intuitively and associatively communicate to chain concepts in dialogue and with graphical notation based on their complementing initiatives.

As explained in publication [P1], we propose that a collaborative learning platform should provide functions to accomplish at least following tasks performed by collaborators: suggesting new ideas accompanied with explanations, referring to earlier suggested ideas, commenting others' ideas, sending coordination messages for selected recipients, synthesizing ideas into compact graphical notation and distributing topics for reconsideration from graphical notation.

In publication [P1] we propose that with the collaborative learning platform a group of collaborators participate together in ideation that can be considered as cumulative generation, reformulation and iteration of ideas and conceptualizations in a process having features of brainstorming. According to her intuition, each collaborator should publish through two separate textual dialogue channels, the first channel containing actual ideas and the second channel more general messages about timetables, tasks to be

done and division of the work. Besides writing, each collaborator should be able to also build and edit a shared *concept map* on the drawing area. All additions and edits, both written and graphical, are submitted to a relational MySQL database running in web server and become then instantly shared by others online via web user interface. Aim of the collaboration is to explore word associations through dialogue and to synthesize newly learned conceptual structures to a mutually agreed concept map.

In publication [P1] we suggest that for all actions performed with the collaborative learning platform are gathered as a *log* into a database, each action associated with a timestamp and contributor's name, and providing a possibility to revert back to earlier states in the ideation. Reviewing earlier actions can be supplemented with a possibility to review filtered sets of previous actions using some criteria, like type of action or contributor. If a learner wants to comment or further elaborate something previously proposed item (idea, message, edit of concept map etc.), it should be referenced by its unique time stamp and contributor's name. This enables the system to track relations between individual contributions and how synthesis is drawn or how topics are distributed for reconsideration.

If a collaborator needs some *stimulation* for producing new ideas she can request a list of concepts that are related to a currently discussed concept which are then retrieved from the Wikipedia online encyclopedia by pressing button "Suggest inlinks" or button "Suggest outlinks". The system retrieves a *Wikipedia article* corresponding to currently discussed concept and identifies articles that are connected to it by an arriving or departing hyperlink and considers their titles as needed concepts. Suitable concepts from the retrieved list can be then added directly to the shared concept map by pressing button "Selected to map".

We have implemented the proposed collaborative learning platform in a web-based *prototype application* with Java. Figure 4.2 (originally published as Figure 2 in publication [P1]) shows an overview of the user interface. We have carried out user tests with volunteers of varied background to confirm the expected benefits of the methodology of the suggested collaborative learning platform. These user tests have indicated that the proposed collaborative learning platform can support collaborative ideation and learning conceptual structures on pretty easy level. We suggest that using the collaborative learning platform online can enable reducing constraints of location and synchronization of timetables of collaborators but on the other hand we also suggest using the collaborative learning platform offline and possibly together at same location to address social needs.

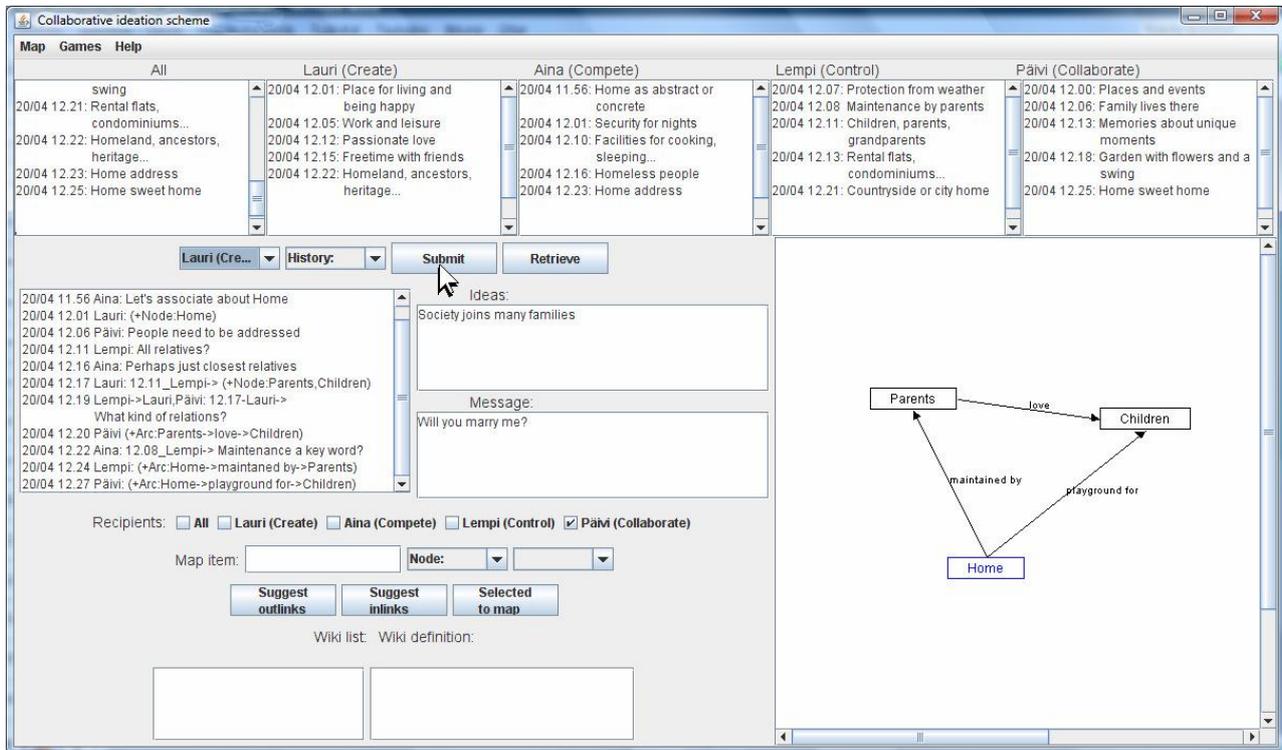


Figure 4.2 (originally published as Figure 2 in publication [P1]). User interface of the prototype proposed in publication [P1].

4.2. Supporting distinctive collaborative roles with Competing Values Framework

Various working strategies (Suthers 2005) and a variety of time scales and activity frequency distributions (Stahl 2006) can suit for *collaborative knowledge construction*. We propose that alternative models can be used to address complementing roles of collaborators taking advantage of personal specific skills supporting an individual to focus on certain type of activities in collaboration. Anyway, among currently actively studied models we think that Competing Values Framework is promising and in publication [P1] we proposed using this model to distribute tasks and to support that these tasks are carried out along a typical activity belonging to each role and task.

Competing Values Framework (CVF) was originally developed from research on the major indicator of effective organizations by asking workers to assess the relative similarity of pairs of effectiveness measures (Quinn & Rohrbaugh 1983) leading to a model with two major dimensions that deal with internal-external orientation and flexibility-stability orientation, and each quadrant associated with certain tasks. *Innovation Genome Model* (IGM) is a more recent variation of Competing Values Framework developed for understanding specifically the different types of innovations that exist in organizations (DeGraff & Quinn 2006). As illustrated with Figure 4.3 (originally published as Figure 1 in publication [P1]), four quadrants of Competing Values Framework and Innovation Genome Model can be described with following complementing *collaborator roles*: innovator-broker (create), producer-director (compete), coordinator-monitor (control) and facilitator-mentor (collaborate). These

roles, in same listing order, can be associated with following management models and tasks: open system model (flexibility and readiness), rational goal model (planning and goal-setting), internal process model (information management and communication) and human relations model (cohesion and morale).

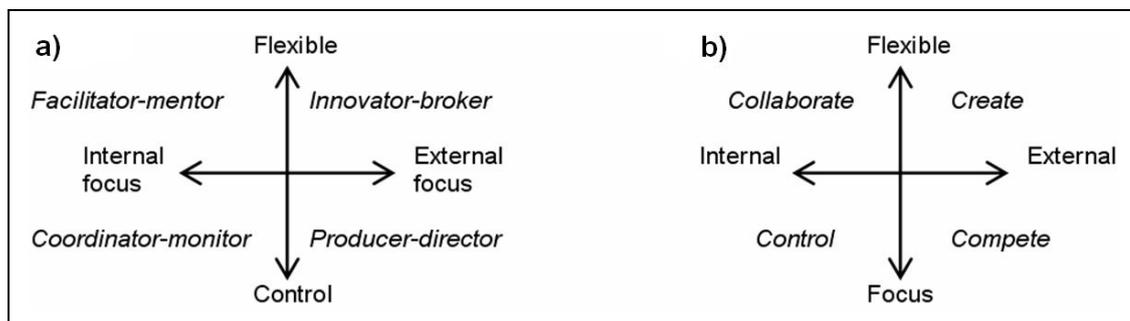


Figure 4.3 (originally published as Figure 1 in publication [P1]). Abstract orientations of organizational management according to the Competing Values Framework (a) and the Innovation Genome Model (b). Both models show two dimensions of qualities for collaboration and corresponding quadrants that represent roles based on dominant characteristics of collaborators.

Since it appears that Innovation Genome Model is not very actively used terminology in research literature so far and we consider it very closely resembling popular Competing Values Framework model, we have decided it appropriate to convert our results about Innovation Genome Model discussed in publication [P1] to be discussed in this dissertation in respect to Competing Values Framework model. Please note also that somewhat confusingly one of the collaborator roles, Facilitator-mentor (collaborate), has naming that includes term collaborate since it is expected to facilitate and mentor collaboration work of the group but naturally all four collaborator roles participate in collaboration in complementing ways addressing their own strengths.

It has been shown that both individuals and organizations can be classified to correspond one of four collaborator roles based on their dominant characteristics and taking into account all of them enables a balanced collaboration workflow ((DeGraff & Quinn 2006); (Buenger et al. 1996); (Gregory et al. (2009); (Yang & Shao 1996)). Despite many alternative attractive models (Cameron et al. 2006), we decided to rely on Competing Values Framework model since it is widely respected and adopted analysis tools (Belasen & Frank 2008) and earlier experimental data enables rich comparative analysis (Kalliath et al. 1999). In publication [P1] we propose using theoretical foundation based on Competing Values Framework model for defining collaborative requirements for computer-assisted collaborative learning platform. We think that this model enables to develop simple and transparent system suitable for practical learning scenarios that can be experimentally evaluated.

4.3. Defining activity patterns and their frequencies to support collaborative roles

In publication [1] we have listed some common tasks for the suggested collaborative learning platform that are associated with each quadrant of Competing Values Framework model (see Table 4.1 (modified version of Table 1 originally published in publication [P1])). We think that tracking these tasks can enable generating automatically appropriate personal support for activities of each collaborator role. Our aim was to identify and describe some activities typically for using user interface of a computer application.

Table 4.1 (modified version of Table 1 originally published in publication [P1]). Suggestion of some typical tasks for collaborator roles based on Competing Values Framework (CVF).

<i>Innovator-broker (create)</i>	<i>Producer-director (compete)</i>	<i>Coordinator-monitor (control)</i>	<i>Facilitator-mentor (collaborate)</i>
<ul style="list-style-type: none"> - submits a lot of ideas - explores accordance of ideas and concept map - adds nodes to concept map - questions constraints 	<ul style="list-style-type: none"> - sets goals for ideation - maintains holistic efficiency - comments concept map - aims at logic flow 	<ul style="list-style-type: none"> - comments ideas - synthesizes ideas to map - edits concept map - references to ideas 	<ul style="list-style-type: none"> - aims at agreement by personal messaging - distributes topics from concept map for reconsideration - adds arcs to concept map - references to concept map

By analysing lists of typical activities identified for each collaborator role ((Quinn & Rohrbaugh 1983); (DeGraff & Quinn 2006); (Carte et al. 2006); (Pounder 2000); (Noypayak & Speece 1998)) we heuristically proposed in publication [P1] coarse frequency distributions for some activities performed with a collaborative learning platform. As we emphasized in publication [P1], the proposed coarse relative activity frequencies tried to loosely indicate how some activities are expected to be performed more by certain collaborator roles than by others. We suggested that empirical testing is needed to acquire actual frequency values. After publication of the publication [P1] we carried out empirical experiments with 66 students having ages in range 15–18 years and representing four roles of Competing Values Framework and we evaluated their collaborative concept map construction process in small groups. For each student we identified which of four major collaborator roles (shown in Table 4.1 (modified version of Table 1 published in publication [P1])) he represents by a questionnaire. Among these 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate).

Without revealing in advance what is the purpose of the questionnaire we asked the student to fill in a competing values self-assessment questionnaire that is adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23–24)) (shown in Appendix T) and among the six sets of four questions corresponding to each four major collaborator roles that role which received highest number of points was selected as the role of the student for collaborative concept map construction process in small groups. In the questionnaire questions 1–6 concern having characteristics of innovator-broker role, then questions 7–

12 producer-director role, next questions 13–18 coordinator-monitor role and finally then questions 19–24 facilitator-mentor role. Based on activities and dialogue we recorded for the individual members of groups we gained collection of statistical data that represents five persons for each of four of collaborator roles of Competing Values Framework, together twenty persons ($n=20$), shown in Table 4.2. Even if sample sizes remain small we think that this experiment offered useful preliminary results.

We decided to use *one-way analysis of variance (ANOVA)* to test for differences in occurrences of twelve activities among four roles of Competing Values Framework based on values shown in Table 4.2 so that we considered so called F value representing the ratio of variance between groups to variance within groups. Before carrying out analysis of variance, we tested data for homogeneity of variance with Fligner-Killeen test of homogeneity of variance that has been considered robust to data that is not normally distributed and this test has a null hypothesis H_{fk} that variances for all samples are equal. It turned out that Fligner-Killeen test of homogeneity of variance for occurrences of twelve activities among four roles of Competing Values Framework, when considering occurrences by each role as samples for an activity, produced p-values in range from 0.09226 to 0.9787 thus meaning that the null hypothesis H_{fk} was not rejected at $p<0.05$.

According to one-way ANOVA, occurrences did not differ significantly among four roles in respect to following activities (since F values remained below critical value of 3.239 that corresponds to degrees of freedom $df_{within_group}=20-4=16$ and $df_{between_groups}=4-1=3$ at $p<0.05$): submitting ideas ($F(3.16)=2.764$; $p = 0.0759$), adding nodes to concept map ($F(3.16)=1.565$; $p=0.237$), adding arcs to concept map ($F(3.16)=0.785$; $p=0.519$), making references to ideas ($F(3.16)=0.187$; $P=0.904$), making and references to concept map ($F(3.16)=0.591$; $p=0.63$), commenting concept map ($F(3.16)=1.087$; $p=0.383$), synthesizing ideas to concept map ($F(3.16)=1.064$; $p=0.392$), distributing topics from concept map for reconsideration ($F(3.16)=0.349$; $p=0.79$), exploring accordance of ideas and concept map ($F(3.16)=0.69$; $p=0.572$), and requesting stimulation for creative thinking ($F(3.16)=0.139$; $p=0.935$).

On the other hand according to one-way ANOVA, occurrences differed significantly among four roles in respect to following two activities (since F values exceeded critical value of 3.239 that corresponds to degrees of freedom $df_{within_group}=20-4=16$ and $df_{between_groups}=4-1=3$ at $p<0.05$): commenting ideas ($F(3.16)=6.39$; $p=0.00472$) and sending coordination messages ($F(3.16)=5.967$; $p=0.00626$). Thus these two activities both required a *Tukey post-hoc test*.

Concerning activity of commenting ideas, Tukey post-hoc comparison of four roles was carried out and it indicated that role of coordinator-monitor (mean 6.0) had significantly higher occurrences than role of innovator-broker (mean 2.0) at $p=0.0064730$; and it indicated also that role of facilitator-mentor (mean 5.4) had significantly higher occurrences than role of innovator-broker (mean 2.0) at $p=0.0210340$; whereas other Tukey post-hoc comparisons were not statistically significant at $p<0.05$.

Table 4.2. Occurrences of twelve activities among four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20).

<i>Groups of Competing Values Framework collaborator roles and their members</i>	<i>Submits ideas</i>	<i>Adds nodes to concept map</i>	<i>Adds arcs to concept map</i>	<i>Makes references to ideas</i>	<i>Makes references to concept map</i>	<i>Comments ideas</i>	<i>Comments concept map</i>	<i>Sends coordination messages</i>	<i>Synthesizes ideas to concept map</i>	<i>Distributes topics from concept map for reconsideration</i>	<i>Explores accordance of ideas and concept map</i>	<i>Requests stimulation for creative thinking</i>
<i>Innovator-broker (create)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
Person1	4	6	9	3	1	2	1	5	15	0	0	1
Person2	6	5	5	2	2	2	4	11	10	0	1	4
Person3	8	7	8	1	3	3	3	12	15	0	2	1
Person4	4	4	5	0	2	1	3	6	9	0	2	2
Person5	7	9	13	5	4	2	4	8	22	2	1	2
Average	5.8	6.2	8	2.2	2.4	2	3	8.4	14.2	0.4	1.2	2
Variance	3.2	3.7	11	3.7	1.3	0.5	1.5	9.3	26.7	0.8	0.7	1.5
Proportion of group	0.187097	0.22963	0.232558	0.314286	0.181818	0.119048	0.176471	0.168	0.23127	0.222222	0.103448	0.277778
<i>Producer-director (compete)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
Person6	3	4	4	2	2	2	4	5	8	0	0	1
Person7	5	10	13	0	6	2	7	11	23	2	3	3
Person8	5	6	5	5	3	5	4	12	11	0	23	2
Person9	6	7	8	0	4	4	6	13	15	0	2	0
Person10	8	3	5	2	2	4	4	14	8	1	1	3
Average	5.4	6	7	1.8	3.4	3.4	5	11	13	0.6	5.8	1.8
Variance	3.3	7.5	13.5	4.2	2.8	1.8	2	12.5	39.5	0.8	93.7	1.7
Proportion of group	0.174194	0.222222	0.203488	0.257143	0.257576	0.202381	0.294118	0.22	0.211726	0.333333	0.5	0.25
<i>Coordinator-monitor (control)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
Person11	2	6	6	1	1	6	3	10	12	0	1	0
Person12	14	7	7	2	1	8	1	25	14	1	2	6
Person13	18	6	16	1	8	3	8	21	22	1	1	0
Person14	7	9	12	2	6	9	8	17	21	0	0	0
Person15	13	4	7	1	4	4	4	17	11	1	7	1
Average	10.8	6.4	9.6	1.4	4	6	4.8	18	16	0.6	2.2	1.4
Variance	39.7	3.3	18.3	0.3	9.5	6.5	9.7	31	26.5	0.3	7.7	6.8
Proportion of group	0.348387	0.237037	0.27907	0.2	0.30303	0.357143	0.282353	0.36	0.260586	0.333333	0.189655	0.194444
<i>Facilitator-mentor (collaborate)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
Person16	8	10	8	5	3	4	5	12	18	0	1	2
Person17	11	7	9	1	2	7	2	12	16	0	0	1
Person18	9	8	11	2	5	6	5	15	19	0	9	4
Person19	10	9	12	0	3	4	4	13	21	0	2	2
Person20	7	8	9	0	4	6	5	11	17	1	0	1
Average	9	8.4	9.8	1.6	3.4	5.4	4.2	12.6	18.2	0.2	2.4	2
Variance	2.5	1.3	2.7	4.3	1.3	1.8	1.7	2.3	3.7	0.2	14.3	1.5
Proportion of group	0.290323	0.311111	0.284884	0.228571	0.257576	0.321429	0.247059	0.252	0.296417	0.111111	0.206897	0.277778
<i>All groups</i>												
Sum of occurrences	155	135	172	35	66	84	85	250	307	9	58	36
F values of ANOVA	2.764	1.565	0.7853	0.1867	0.5906	6.390	1.087	5.967	1.064	0.3492	0.6896	0.1391

Concerning activity of sending coordination messages, Tukey post-hoc comparison of four roles was carried out and it indicated that role of coordinator-monitor (mean 18.0) had significantly higher occurrences than role of innovator-broker (mean 8.4) at $p=0.0042674$; and it indicated also that role of coordinator-monitor (mean 18.0) had significantly higher occurrences than role of producer-director (mean 11.0) at $p=0.0395745$; whereas other Tukey post-hoc comparisons were not statistically significant at $p<0.05$.

These just described results of one-way ANOVA should be considered with some uncertainty, for example due to limited sample sizes, but they offer some insight for modeling activity patterns of four different roles of Competing Values Framework.

Based on Table 4.2 we still wanted to present in compact form the frequency distributions for collaborative activities in respect to each four major collaborator role in Table 4.3 (modified version of Table 2 originally published in publication [P1]). These new empirical values differ from the previous values heuristically suggested in publication [P1] and we suggest that these new frequency distributions should be given priority when implementing an automated monitoring and guidance system for creative collaborative work as suggested in publication [P1]. The more general listing of activities in Table 4.1 ((modified version of Table 1 originally published in publication [P1])) is slightly reformulated in Table 4.3 (modified version of Table 2 originally published in publication [P1]) to suit more specific context of the collaborative learning platform implemented with prototype.

As already mentioned, in our proposed method each collaborator is asked to fill in a self-assessment questionnaire adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23–24)) to identify her dominant collaborator role in respect to Competing Values Framework. However sometimes it can turn out that the persons available for collaboration do not have a balanced distribution of all four collaborator roles. To address also these situations, we suggest that based on the set of questions of questionnaire receiving the highest number of points the most matching collaborator roles are given to participants but an additional requirement is to ensure that each of the four roles are taken by someone and with less than four persons requires a person being responsible for several roles. Thus sometimes a person needs to take a collaborator role that is not the most dominant for her but anyway she is among the available persons the person who has received the highest number of points in respect to set of questions concerning that role.

We think that each collaborating group benefits from having a freedom to decide itself about practical guidelines for practically performing their creative work together, including sharing responsibilities and agreeing on timing patterns. We think that the complementing efforts from each collaborator should be let to be generated spontaneously without any strict predefined constraints. Anyway, to support exploitation of the specific complementing strengths of each collaborator we propose that a collaborative learning platform monitors activity patterns of each collaborator role and if they differ sufficiently from the expected activity profiles the system asks the representatives of this role to adjust that activity to follow the expected profile. This practise aims to ensure most productive collaboration. For example, the system can

measure activity distribution during preceding 5 minutes and if the measured activity of a collaborator differs with a sufficient number of percents from her expected activity profile she will be informed and asked to adjust her activity to more closely match expected activity profile. If the situation does not change after three reminders the system sends a notice also to other collaborators. In publication [P1] we suggested that if activity departs from expected activity profile over 20 percent the system intervenes but based on later experiments we suggest giving tolerance for variation until the activity frequencies reach a new maximum or a minimum value, as discussed later in this Chapter 4.

Table 4.3 (modified version of Table 2 originally published in publication [P1]). Some empirically gained activity frequencies for 12 activities among four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20). For each activity the highest activity frequency is supplied with an asterisk (*) and if there are more than one activity sharing this highest value all of them are supplied with a double asterisk (**). For example, in a collaborative ideation session a person having Innovator-broker role is expected to contribute about 18.7 percent of all activities dealing with “submitting ideas”, Producer-director about 17.4 percent, Coordinator-monitor about 34.8 percent and Facilitator-mentor about 29.0 percent respectively. These empirically gained values can be contrasted with heuristically approximated values that we published in publication [P1] and can be seen in Appendix R.

<i>Type of activity</i>	<i>Innovator-broker role (create)</i>	<i>Producer-director role (compete)</i>	<i>Coordinator-monitor role (control)</i>	<i>Facilitator-mentor role (collaborate)</i>	Σ
Submits ideas	0.187096774	0.174193548	0.348387097*	0.290322581	1.000
Adds nodes to concept map	0.22962963	0.222222222	0.237037037	0.311111111*	1.000
Adds arcs to concept map	0.23255814	0.203488372	0.279069767	0.284883721*	1.000
Makes references to ideas	0.314285714*	0.257142857	0.200000000	0.228571429	1.000
Makes references to concept map	0.181818182	0.257575758	0.303030303*	0.257575758	1.000
Comments ideas	0.119047619	0.202380952	0.357142857*	0.321428571	1.000
Comments concept map	0.176470588	0.294117647*	0.282352941	0.247058824	1.000
Sends coordination messages	0.168000000	0.220000000	0.360000000*	0.252000000	1.000
Synthesizes ideas to concept map	0.231270358	0.211726384	0.260586319	0.296416938*	1.000
Distributes topics from concept map for reconsideration	0.222222222	0.333333333**	0.333333333**	0.111111111	1.000
Explores accordance of ideas and concept map	0.103448276	0.500000000*	0.189655172	0.206896552	1.000
Requests stimulation for creative thinking	0.277777778**	0.250000000	0.194444444	0.277777778**	1.000

It needs to be emphasized that we think that useful activity frequency distributions should be measured for also many other types of activities than those shown in Table 4.3 (modified version of Table 2 originally published in publication [P1]). We think that with increasing number of parallel activity measures it could be possible to offer better guidance for each type of collaborative complementing efforts that can be generated by

specific strengths belonging to representatives of each possible collaborator role of Competing Values Framework. Besides Competing Values Framework, we think that also for other types of theoretically motivated collaborator roles it could be possible to similarly identify strengths for each collaborator and the system could monitor that expected activity profiles most fertile for collaboration are met and if not the collaborators are asked to reach the expected activity profiles. Anyway, we decided to limit the scope of publication [P1] to cover estimating the activity frequencies only for the model Competing Values Framework.

It is challenging to empirically measure the pedagogical effect coming from automated guidance that aims to keep activity frequencies of collaborators close to the expected values. Anyway after publication of publication [P1] we carried out empirical user tests that seemed to indicate that learners maintaining their activity frequencies most regularly close to expected values could generate more rich contribution to collaborative process of building knowledge structures than learners maintaining their activity frequencies less regularly close to expected values.

We think that further more detailed analysis of correlation and causality about for example timing practices concerning distribution of different activities of collaborators and following a specific order of performance can reveal new insight about how each individual collaborator role can proceed in collaboration activities most fruitfully and naturally thus offering best benefit both individually and collectively. Thus by getting more understanding about the characteristics and models governing each collaborator's typical fertile activities the system could then support best the learner by intervening fruitfully and supportingly at moments when it seems that the learners would benefit from doing something specific that however she now has not yet figured out to do.

Individual variation among persons having same collaborator role, causes that the suggested activity frequencies should not be seen as strict values but instead indicating approximate tendencies. Our empirical results with Competing Values Framework show that collaborator role of Coordinator-monitor has leading frequency in four types of activity, Facilitator-mentor has in four types of activity, Producer-director has in three types of activity and Innovator-broker in one type of activity. However, this does not necessitate that role Innovator-broker is more passive than other roles in collaboration in respect to all kinds of imaginable activities. If activity frequencies for additional alternative types of activities are measured in future research it may turn out that the number of leading frequencies for each role and balance of them is completely different. An important task for future research is to try to find most expressive way to classify and identify collaborator roles types, their strengths and measurable activities for each role.

We present now here additional findings and how they can be incorporated into our original model and how they affect our previous analysis and conclusion reported in the publication [P1]. It appeared that our heuristically approximated frequencies (see Appendix R) differed from the experimentally gained frequencies with some major features. Firstly, the heuristically approximated frequencies had a general difference that each unique type of performance had a distribution of frequencies that was unrealistically wide. This means that despite some extreme individual variations, the

general average difference between different collaborator roles remains in empirical values only in relatively small range. So instead of having several multiples of other frequencies (other frequencies being even 200–400 percent greater than others) typically we observed at most 200 percent greater frequencies.

Also our later experiments showed that we originally defined a too tight and strict threshold (20 percent) for the monitoring system to intervene with encouraging the user to modify the frequency of the activities belonging to their collaborator role. We now consider that the system should not be directly intervening depending on a fixed percentage in the activity level for a certain collaborator role but instead be relative to the broader distribution pattern of activity frequencies of the collaborator roles. We suggest giving tolerance for variation until the activity frequencies reach a new maximum or a minimum value. This means that for each type of activity the system does not intervene as long as the activity role having the highest value in expected activity frequency profile has not yet been passed above by the collaborator representing another role and as the activity role having the lowest value in expected activity frequency profile has not yet been passed below by the collaborator representing another role.

As briefly mentioned in publication [P6], our later supplementary empirical experiments with a group of 66 students also indicated that persons representing different collaborator roles based on Competing Values Framework produced distinctive exploration patterns in collective concept mapping as suggested in publication [P1].

Table 4.4 shows the conceptual relationships having the highest number of occurrences for each of four collaborator roles of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (linking direction was not specified in relationships of concept maps). For each collaborator role we have indicated with an asterisk (*) those relationships that do not exist in listings of other collaborator roles in this table. Since among 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate) we show for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Even if from this small sample strong conclusions cannot be made, in Table 4.4 it seems to us that certain conceptual relationships occurred more frequently in concept mapping by certain collaborator roles of Competing Values Framework, and these promoted relationships can possibly even have same correlations with the characteristics associated with this collaborator role according to Competing Values Framework. Persons representing Innovator-broker role (create) associated with flexibility and readiness promoted for example relationship education↔school. Persons representing Coordinator-monitor role (control) associated with information management and communication promoted for example relationship school↔teacher. Persons representing Producer-director role (compete) associated with planning and goal-setting promoted for example relationship education↔work. Persons representing Facilitator-mentor role

(collaborate) associated with cohesion and morale promoted for example relationship animal↔god.

Table 4.4. In exploration patterns in collective concept mapping those conceptual relationships having the highest number of occurrences for each of four collaborator roles of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (linking direction was not specified in relationships of concept maps). For each collaborator role we have indicated with an asterisk (*) those relationships that do not exist in listings of other collaborator roles in this table. Since among 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate) we show for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Facilitator-mentor role (collaborate) (n=14)		Producer-director role (compete) (n=24)			Coordinator-monitor role (control) (n=14)		Innovator-broker role (create) (n=14)	
relationship	occurrences	relationship	occurrences (n=24)	normalized occurrences ** (estimates corresponding to n=14)	relationship	occurrences	relationship	occurrences
family↔home	3	family↔love	5	2.92	friend↔school	4	joy↔sorrow	3
family↔love	3	food↔water *	4	2.33	father↔mother *	3	birth↔death	2
birth↔death	2	education↔work *	3	1.75	family↔friend *	3	animal↔dog *	2
friend↔love	2	family↔living *	3	1.75	home↔house *	2	friend↔school	2
animal↔god *	2	friend↔love	3	1.75	family↔mother *	2	death↔sorrow *	2
family↔father	2	air↔water *	2	1.17	family↔father	2	death↔living *	2
study↔work *	2	fire↔ground *	2	1.17	child↔wife *	2	cat↔dog	2
death↔nature *	2	air↔ground *	2	1.17	animal↔family *	2	education↔school *	2
birth↔nature *	2	family↔home	2	1.17	friend↔hobby *	2	family↔happiness *	2
living↔purpose *	2	joy↔sorrow	2	1.17	school↔teacher *	2		
		breathing↔human *	2	1.17	school↔work *	2		
		friend↔pet *	2	1.17	birth↔death	2		
					diversity↔nature *	2		
					family↔reproduction *	2		
					birth↔reproduction *	2		
					drink↔food *	2		
					cat↔dog	2		

Based on Table 4.4, Table 4.5 shows the most occurring concepts in conceptual relationships having the highest number of occurrences for each collaborator role of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role. For each collaborator role we have indicated with an asterisk (*) those concepts that do not exist in listings of other collaborator roles in this table. Like in Table 4.4 we show also in Table 4.5 for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Similarly as with Table 4.4, even if from this small sample strong conclusions cannot be made, in Table 4.5 it seems to us that certain concepts occurred more

frequently in concept mapping by certain collaborator roles of Competing Values Framework, and these promoted concepts can possibly even have same correlations with the characteristics associated with this collaborator role according to Competing Values Framework. Persons representing Innovator-broker role (create) associated with flexibility and readiness promoted for example concept happiness. Persons representing Coordinator-monitor role (control) associated with information management and communication promoted for example concept diversity. Persons representing Producer-director role (compete) associated with planning and goal-setting promoted for example concept breathing. Persons representing Facilitator-mentor role (collaborate) associated with cohesion and morale promoted for example concept god.

Table 4.5. In exploration patterns in collective concept mapping those most occurring concepts in conceptual relationships having the highest number of occurrences for each collaborator role of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (based on Table 4.4). For each collaborator role we have indicated with an asterisk (*) those concepts that do not exist in listings of other collaborator roles in this table. Like in Table 4.4 we show also in Table 4.5 for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Facilitator-mentor role (collaborate) (n=14)		Producer-director role (compete) (n=24)			Coordinator-monitor role (control) (n=14)		Innovator-broker role (create) (n=14)	
concept	occurrences	concept	occurrences (n=24)	normalized occurrences ** (estimates corresponding to n=14)	concept	occurrences	concept	occurrences
family	8	family	10	5.83	family	11	death	6
love	5	love	8	4.67	friend	9	sorrow	5
birth	4	water *	6	3.5	school	8	dog	4
death	4	friend	5	2.92	father	5	school	4
nature	4	air *	4	2.33	mother *	5	joy	3
home	3	food	4	2.33	birth	4	animal	2
animal	2	ground *	4	2.33	reproduction *	4	birth	2
father	2	education	3	1.75	animal	2	cat	2
friend	2	living	3	1.75	cat	2	education	2
god *	2	work	3	1.75	child *	2	family	2
living	2	breathing *	2	1.17	death	2	friend	2
purpose *	2	fire *	2	1.17	diversity *	2	happyness *	2
study *	2	home	2	1.17	dog	2	living	2
work	2	human *	2	1.17	drink *	2		
		joy	2	1.17	food	2		
		pet *	2	1.17	hobby *	2		
		sorrow	2	1.17	home	2		
					house *	2		
					nature	2		
					teacher *	2		
					wife *	2		
					work	2		

Interestingly in both Table 4.4 and Table 4.5 it turned out that collaborator roles Producer-director role (compete) and Facilitator-mentor role (collaborate) seemed to have connectivity for concept love and collaborator roles Innovator-broker role (create) and Coordinator-monitor role (control) seemed to have connectivity for concept school. Thus when considering four quadrants of Competing Values Framework the two roles belonging to opposite quadrants seem to possibly be coupled by prioritizing at least to some extent certain concepts and certain relationships.

4.4. Findings and their relation to the entity of the dissertation

In publication [P1] we proposed an educational framework that we referred to as a collaborative learning platform. The guidance automatically generated by the collaboration platform should enable enhancing each collaborator's creative output in accordance with the collaborator role they represent based on Competing Values Framework. In publication [P1] we suggested performing further extensive user tests that can evaluate our proposed collaborative learning platform and its methods in various educational contexts. We are interested in extracting statistical and causal correlations in the activity patterns of persons representing different collaborator roles.

Many traditional collaborative ideation techniques have been based on following some strict rules. However this may not take well into account the constantly evolving dynamics of a group and how the goals change through intermediary steps. The proposed collaborative learning platform tries to enable the creative resources of the group and its members to flexibly adapt and respond to the impulses gained in the flow of ideation. Therefore, the collaborative learning platform does not give strict constraints for the group activities although it makes the process rather fuzzy. Anyway, in all creative work one needs to accept some uncertainty and leave room for spontaneity. Besides individual analysis, we expect to be fruitful to examine interaction patterns between collaborators and how they accumulate their knowledge together. This could enable new ways to support characteristics of each pair-wise communication in a group. Identifying general principles of interaction patterns could also provide insight about evolution of ideas in dialogue threads. One aspect of collaboration that requires specific emphasis in future systems is delivering a balanced ideation session that exploits available resources in a convergent fashion.

There are various theoretical approaches trying to explain and model diverse collaborator roles and thus our proposal presented in publication [P1] should be seen primarily as a base for developing supportive activities. We expect this initial collaborative learning platform to be applicable even irrespective from which actual model of collaborator roles are applied to give guidance for the collaborators to keep certain activity patterns following inside some suggested threshold limits. We provide a concrete illustration of this activity control and support with model based on Competing Values Framework and providing empirically gained activity frequency values concerning specific activities of collaborative knowledge construction process. Critical analysis about the publication [P1] shows that the original work has some shortcomings due to limited experimental testing. However, accompanied with results gained in augmenting empirical user tests we think that the work of publication [P1] offers a promising new type of computational collaborative learning platform for supporting educational collaborative activities and in addition offers experimentally defined parameter values to guide activities to follow fertile patterns. Despite the publication [P1] refers to less known variation of Competing Values Framework (i.e. Innovation

Genome Model) we think that our work described in publication [P1] can still well maintain its credibility since they are closely related models.

We think that publication [P1] fruitfully described a workflow for collaborative learning relying on mechanisms that are closely related to wiki based architecture and philosophy for using wikis. We think that the characteristics of collaborative learning platform described in publication [P1] forms a base of educational framework that can be flexibly extended in functionality with various computational methods suggested and described in detail in later publication that form this dissertation. Publication [P1] draws a basic outline about new model of learning environment, actors and their requirements and how on abstract level to address the needs of learners with software. In publication [P1] we have described some basic elements needed in the user interface and how they are used to convey and handle messages and representations about educational information.

In publication [P1] we introduce the idea of retrieving supplementing knowledge from the Wikipedia to support individual and collaborative knowledge adoption and acquisition; in later proposals we decided to focus analysis just on outlinks, not inlinks. In publications [P2], [P3] and [P4] we elaborate this idea of exploiting knowledge structure of the Wikipedia for letting the learner to explore pedagogically meaningfully along chained concepts. Also mechanism allowing reverting to earlier stages of knowledge construction process and keeping clear unique referencing system to earlier pieces of contribution (log of activities enabling individual tracking) have early indications and implication about the proposals that are presented in publications [P5] and [P6]. Publications [P5] and [P6] elaborate using wiki structure to combine individual contributions given as concept maps to a bigger collective entity and using the knowledge structure of the Wikipedia to find shortest path to traverse conceptual chains shared inside an entity formed by combining individual concept maps. The method could be enhanced with real-time updates (not requiring to press submit button), now possible to have conflicts if concurrent editing performed.

Chapter 5. Generating pedagogical concept maps from the Wikipedia

In publication [P2] we propose a new computational method for guided generation of pedagogical concept maps based on the hyperlink network of the *Wikipedia online encyclopedia* (<http://en.wikipedia.org>). On a more general level, we propose methodology for generating adaptive concept maps from open access online knowledge resources, such as wikis. Wikis are web sites freely built and edited by a community of volunteers. Following the principles of our method we have designed and implemented a prototype application extracting semantic relations from the articles of the Wikipedia free online encyclopedia. We think that corresponding to an *intelligent tutoring system* our proposed method enables creating customized learning objects in real-time based on collaborative recommendations.

We now here first explain basic idea and motivation about building pedagogical concept maps based on hyperlink network of the Wikipedia and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P2]. Figure 5.1 illustrates main idea of the method proposed in publication [P2].

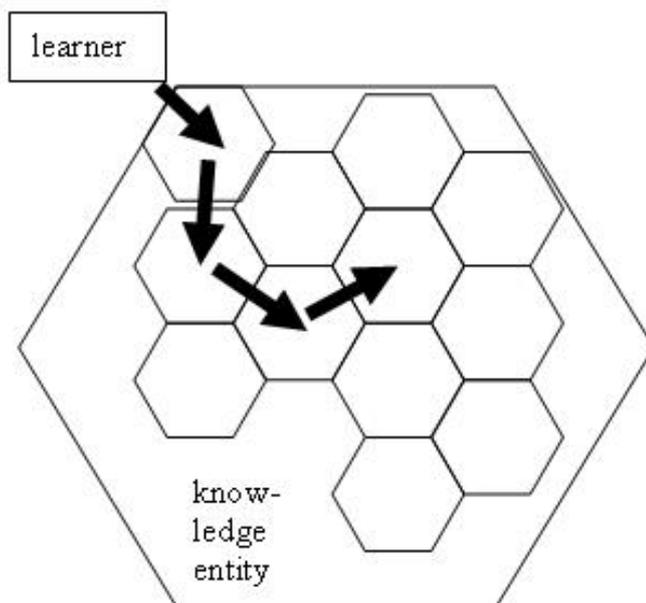


Figure 5.1. Main idea of the method proposed in publication [P2] for generating pedagogical concept maps based on exploring in the hyperlink network of the Wikipedia.

In contrast with Figure 4.1 in which linked hexagons represented a collectively generated and gradually built concepts map, in Figure 5.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. In addition, instead of having collaborative learners, we are here now defining a strategy for a single learner traversing hyperlinks between articles. A shared edge between two hexagons indicate defined hyperlink between Wikipedia articles (arriving or departing hyperlink). The learner's exploration path in the hyperlink network so far is shown by a chain of arrows.

5.1. Exploiting the knowledge structure of the Wikipedia online encyclopedia

Previous research has identified various methods to access appropriate knowledge in the Wikipedia. Gregorowicz and Kramer (Gregorowicz & Kramer 2006) proposed to generate a robust term–concept network from the Wikipedia addressing actual concepts, alternate terms and related concepts, and Milne and Witten (Milne & Witten 2008) proposed to disambiguate term–article mappings by exploiting three features: conditional probability, collocation and link distribution similarity. Gabrilovich and Markovitch (Gabrilovich & Markovitch 2009) suggested representing natural language semantics in a high-dimensional space of concepts based on calculating tf-idf weights (i.e. term frequency – inverse document frequency weights) for corresponding Wikipedia articles and reported that newer temporal versions of the Wikipedia gave a small but consistent improvement, and that use of inter-article links improved accuracy.

Knowledge mining from the Wikipedia has already been widely applied for various tasks (Medelyan et al. 2009), for example supporting validation of relevant information, combining various knowledge resources and implementing online association thesaurus ((Blohm et al. 2008); (Hoffmann et al. 2009); (Nakayama 2008)). Nakayama et al. (Nakayama et al. 2008) showed that link structure mining improves both the accuracy and the scalability of semantic relations extraction from the Wikipedia. They propose three processes optimized for Wikipedia mining: fast pre-processing, part-of-speech tag tree analysis and mainstay (statement) extraction.

5.2. Educational exploration in the hyperlink network of the Wikipedia

The Wikipedia has been exploited educationally for returning specific answers to questions by an interface for command line queries (Kaisser 2008), biography quizzes (Higashinaka et al. 2007), and a tool assisting Wikipedia authors (Jijkoun & de Rijke 2006). However, indication of promising learning paths, unconstrained exploration and intuitive visualizations are typically missing in current solutions. (Kumar 2006) argues that in intelligent tutoring systems managing domain models and learner models can get support from so called “domain concept maps”. There does not currently exist many solutions supporting non-predefined verbal relations between concepts in the ontology and exploiting concept maps. (Zouaq et al. 2007b) proposed a layered model that with

natural language processing extracts concept maps from documents and organizes the generated knowledge into Web Ontology Language (OWL) document ontologies. By extracting concept-verb-concept triples and other relations with a parser their method generates a semantic network which can be further modified by a human expert with a visual map editor.

In publication [P2] we suggested extending the use of *ontologies* and *concept maps* into semantic modelling with the supply of the Wikipedia. We considered that the collaboratively maintained knowledge structure of the Wikipedia can serve as a both adaptive and expressive frame for implementing customized learning objects. We proposed extracting semantic relations from hyperlinks of an article and parsing compact explanations about them. The learner is encouraged to freely explore in real-time in the adaptively evolving personalized content based on hyperlink network of the Wikipedia. At the same time the path of exploration is represented in the form of gradually expanding concept maps. Positively, this proposed approach can be carried out with relatively simple computational methodology and ensures great personal freedom for the learner's exploration with an underlying optimistic hypothesis that she knows herself best her needs in selecting most suitable paths.

We do not know previous work similar to our proposal in respect to learner-driven generation of labelled concept maps extracted from Wikipedia hyperlinks. For example, Wikipedia Roll merely focuses on browsing hyperlinks grouped in article's subchapters (Muthesius et al. 2008). Outside the Wikipedia domain, resembling concept mapping efforts include (Dey et al. 2007) and (Nasharuddin et al. 2008).

Natural and social networks, including the Wikipedia, form hierarchical cluster structures even without human coordination. These structures emerge following so called power law in for example article sizes, the number of connecting links, editing times and collaboration distribution (Buriol et al. 2006). These structures support the network in minimizing average paths between nodes and maximizing ability to recover if a random node fails. We suggest that management of ideas and concepts in human mind and collaborative learning may rely on an analogous cluster structure and thus favourable learning paths could rest on experimenting with the hyperlink structure of the Wikipedia. Our proposed method tries to facilitate exploiting these cluster structures for various educational purposes.

Since the knowledge in a wiki framework is already initially organized following human intuition, there is no need for extensive evaluation in large learning content space or heavy mining to reformulate information and to interpret it to a human user. A simple algorithm suffices to offer collectively generated recommendations for the learner how to gradually build learning paths along hyperlinks between Wikipedia articles. Even the choice between alternative learning paths can be given directly to the learner since the initial organization of knowledge and previous steps should be intuitive enough to support learner to make the best decisions for herself.

5.3. Building pedagogic concept maps from the Wikipedia

The proposed method is based on extracting semantic relations from Wikipedia articles on the request of a learner and gradually building a concept map online representing learning paths following the learner’s initiative and interests. Evolving concept map provides functionalities of a customized learning object and an intelligent tutoring system that can be flexibly modified and reused. Table 5.1 illustrates the main activities involved in generation of pedagogic concept maps from the hyperlink network of the Wikipedia by using the proposed method.

Table 5.1. Main activities for the generation of pedagogic concept maps from the hyperlink network of the Wikipedia.

Step 1. Retrieval of a Wikipedia article as a html document from the web servers of the Wikipedia Foundation.
Step 2. Extraction of hyperlinks and phrases around them.
Step 3. Adding Penn Treebank part-of-speech conventions and tokenizing words with tags representing its role in sentence to the extracted phrases.
Step 4. Identifying verb closest to hyperlink and segment between surrounding nouns to form relation statement.
Step 5. Displaying list of hyperlinks target articles and their relation statements.
Step 6. Generating expanding concept map based on the hyperlinks that the learner decides to traverse.

The learner begins exploration by adding an initial concept about the learning topic manually as the first node of the concept map. Then the method retrieves a Wikipedia article having a title that matches the concept given by the learner. From the retrieved Wikipedia article the method extracts every hyperlink (consisting of the title and url (uniform resource locator) of target article and the anchor text) and the sentence surrounding it. For each extracted hyperlink the method generates a compressed explanation phrase based on the surrounding sentence. The compression is done by identifying a verb nearest to the hyperlink and taking into account only the text sequence between two adjacent nouns around this verb from the sentence and eliminating other less relevant words (for example redundant occurrences of titles of current article and hyperlink’s target article can possibly be eliminated from the sentence).

The hyperlinks are shown to the learner as a scrollable list in the original order of appearance thus promoting core definitions usually in the beginning of an article. Each row shows the title of hyperlink and its short explanation phrase. Following her intuition and evaluation, the learner can select one or more hyperlinks from the list. For the most recently selected hyperlink, the full original sentence is shown in a separate textbox letting the learner to verify that the compressed explanation phrase holds. By pressing the button “Selected to map” she can add selected hyperlinks as new child

nodes of the currently active node, connected with directed arc. The node label is derived from the title of hyperlink and the arc label from the explanation phrase respectively. After adding new linked nodes, they can be used as initial concepts for further exploration. Step by step the learner establishes and proceeds in the most promising learning path for her needs.

We used *Apache Commons HttpClient* module to submit queries and to retrieve articles from the Wikipedia (Apache Commons 2009). We used CRFTagger module developed by Xuan-Hieu Phan as a *module of part-of-speech tagging* for English that according to the module’s documentation relies on first-order Markov conditional random fields model trained on Wall Street Journal portion of the Penn Treebank corpus and is said to achieve accuracy of 97 percent (Phan 2006). Compared with rule based or lexicon dependent approach, a typical advantage of a Markov model is adaptivity to varying lexical contexts although at the cost of some accuracy. We designed and implemented the algorithms that extract hyperlinks with surrounding sentences and generate explanation phrases, and the algorithm coordinating existing modules. Figure 5.2 (originally published as Figure 1 in publication [P2]) illustrates the user interface of the prototype we have implemented based on the proposed method.

We wanted to verify that the proposed educational method in which the learner explores the hyperlink network of the Wikipedia can offer pedagogically meaningfully chainable segments of knowledge. Thus we have conducted experiments with our prototype by generating concept maps from the Wikipedia and evaluating their pedagogical quality with human reasoning. From a listing of 1000 most visited articles of the Wikipedia in 2008 (Wikistics Falsikon 2009) we randomly retrieved 20 articles and automatically generated an explanation phrase for each hyperlink they provided.

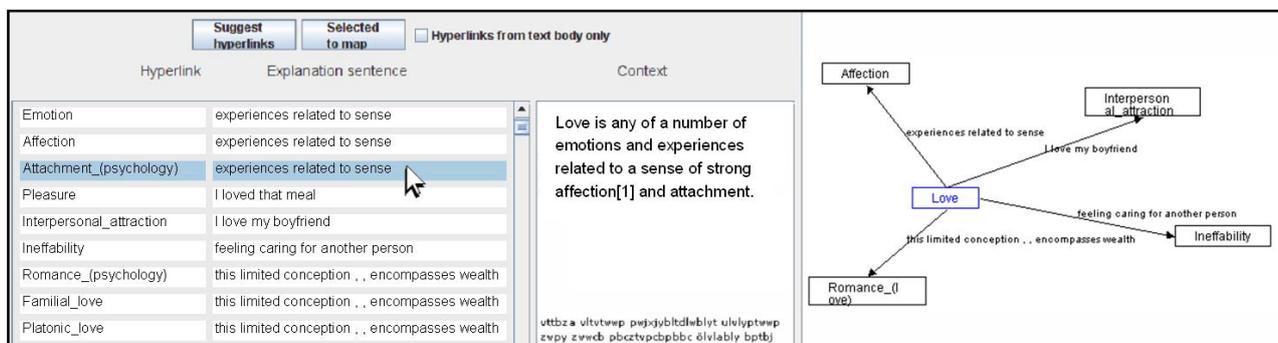


Figure 5.2. User interface of prototype while exploring the hyperlinks of Wikipedia article about Love (a detail).

As shown in Table 5.2 (originally published as Table 1 in publication [P2]), for all articles together, 81 percent of explanation phrases appeared to be useful, 11 percent misleading and 8 percent fuzzy. Only exception to the general success rate of at least 69 percent, is article about “Philippines” with 33 percent success only. A closer look revealed this being apparently due to having a lot of sentences referring to various cultural and geographical concepts that the method could not succeed in mapping correctly. We consider current success rate surprisingly good and convincing, especially in respect to high compression of explanation sentences.

To better understand educational potential of knowledge structures in the Wikipedia, we wanted to have a possibility to compare connectivity between 102 core concepts (shown in Table 3.4) in collection of concept maps drawn by students and in collection of corresponding 102 articles in the Wikipedia. To make this comparison process more stable and transparent we decided to mainly rely on one fixed temporal version of the Wikipedia articles and hyperlink network that have been available online in the Wikipedia in the beginning of March 2008 and we used most preferably the last edited versions of articles and hyperlinks by date 3 March 2008. This specific date was partially motivated by experiments that we made with an online database service “Six degrees of Wikipedia” enabling to make queries about connectivity of Wikipedia articles based on version 3 March 2008 (Dolan 2011) (as discussed in publication [P6] and Chapter 9).

Table 5.2 (originally published as Table 1 in publication [P2]). Distribution of useful, misleading and fuzzy explanation phrases generated for hyperlinks of twenty Wikipedia articles separately. The success percentage indicates the proportion of useful phrases to all phrases.

	Lion	Italy	Radiohead	Jesse McCartney	Hancock (film)	Pink Floyd	Bow Wow	Philippines	Judaism	John Cena	Kenya	Linux	Star Wars: The Clone Wars (film)	Traq War	Terminator Salvation	ABBA	Florida	Two-Face	Religion	Peru	Σ
Explanations	38	48	29	5	18	32	12	18	46	29	15	23	21	39	18	27	15	36	42	32	543
- useful	33	41	24	4	15	22	11	6	39	25	14	16	15	28	15	26	12	29	38	26	439
- misleading	4	5	3	0	2	5	0	7	5	4	1	4	3	4	1	1	2	3	3	5	62
- fuzzy	1	2	2	1	1	5	1	5	2	0	0	3	3	7	2	0	1	4	1	1	42
Success	87 %	85 %	83 %	80 %	83 %	69 %	92 %	33 %	85 %	86 %	93 %	70 %	71 %	72 %	83 %	96 %	80 %	81 %	90 %	81 %	81 %

Appendix G shows how much in *hyperlink network of the Wikipedia* each of the 102 core concepts is linked (with a specified direction) to any possible concept or to 102 core concepts. Appendix G also shows how much linking departs from the *full text section* of each Wikipedia article ((i.e. when considering those hyperlinks that are mentioned in the full text in Wikipedia article) or from only *intro text section* of each Wikipedia article (i.e. when considering only those hyperlinks that are mentioned only in the very beginning of text in Wikipedia article, typically before table of index, thus often trying to offer a relatively compact definition about the article). In addition, for each of 102 core concept it is shown how much it occurs as start concept, end concept or start/end concept in hyperlinks.

Appendix H extends information of Appendix G by showing how much in *concept maps generated by students* each of 102 core concepts is connected (without a specified direction, thus either as start/end concept) to 102 core concepts when considering each connection with or without duplicates, considering only relationships mentioned by at least two students (based on 145 core relationships shown in Table 3.9).

It turned out that in the Wikipedia altogether 20512 hyperlinks (14907 unique hyperlinks) depart from full text section of 102 core concepts to any possible concept, average value being 201.1 hyperlinks and median value 151.5 hyperlinks. When limiting observation to only intro text section, altogether 1243 hyperlinks (1055 unique hyperlinks) depart from intro text section of 102 core concepts to any possible concept,

average value being 14.0 hyperlinks and median value 11 hyperlinks. We identified that between 102 core concepts there are altogether 422 unique hyperlinks in hyperlink network of the Wikipedia.

When considering only linking between 102 core concepts and hyperlinks departing from full text section, 85 of 102 core concepts occur as end concept in hyperlinks and 88 of 102 core concepts as start concept in hyperlinks, and 93 of 102 core concepts as start or end concept in hyperlinks. For hyperlinks departing from full text section, on average a concept belonging to 102 core concepts occurs as an end concept in hyperlink for 4.1 other core concepts, as a start concept in hyperlink for 4.1 other core concepts, and as a start or an end concept in hyperlink for 6.4 other core concepts (median values being 3.5, 3 and 5 respectively).

When considering only linking between 102 core concepts and hyperlinks departing from only into text section, 43 of 102 core concepts occur as end concept in hyperlinks and 60 of 102 core concepts as start concept in hyperlinks, and 70 of 102 core concepts as start or end concept in hyperlinks. For hyperlinks departing from only into text section, on average a concept belonging to 102 core concepts occurs as an end concept in hyperlink for 1.1 other core concepts, as a start concept in hyperlink for 1.0 other core concepts, and as a start or an end concept in hyperlink for 1.8 other core concepts (median values being 1, 0 and 1 respectively).

Thus it seems that when having limited computational resources a simple and relatively successful solution to filter useful hyperlinks to support exploration of hyperlinks can be to rely on just those hyperlinks that depart from only into text section of a Wikipedia article since even in our small sample of 102 core concepts there seems to remain some kind of connectivity so that there is on average one hyperlink linking from a core concept to some other core concept.

These results about hyperlinks in the Wikipedia can be contrasted with results about relationships in concept maps drawn by students, considering only relationships mentioned by at least two students. In concept maps when considering only relationships between 102 core concepts, 75 of 102 core concepts occur as start or end concept in relationships (75 of 102 core concepts if word brother can be seen representing word sister since in the Wikipedia both words represent word sibling). On average a concept belonging to 102 core concepts occurs as a start or an end concept in relationship for 2.8 other core concepts (median value being 1).

Based on Appendix H for each of five comparison tests Table 5.3 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and the number of unique start/end concepts in relationships of concept maps for each of 102 core concepts. It turns out that only one of five null hypothesis, the null hypothesis H_k s of Bootstrap version of Kolmogorov-Smirnov two-sample test, becomes rejected based on significance level of $p < 0.05$.

To facilitate identifying possible similarities between frequency distributions of Appendix H we transformed for representation of Table 5.3 the frequency values into approximately same range of values thus forming scaled frequency distributions so that

sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts has a weighting parameter 1 and scaled frequency distribution of number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts has a weighting parameter 3.3. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.3. Degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and the number of unique start/end concepts in relationships of concept maps for each of 102 core concepts.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (scaled)	number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.02651 (null hypothesis Hks rejected)	gamma=0.1418564 (standard error 0.1581316); null hypothesis Hgk not rejected (p=0.3696773)	rho=0.1642973; null hypothesis Hsr not rejected (p=0.09892)	tau=0.1251973; null hypothesis Hkr not rejected (p=0.09208)

Based on Appendix H Figure 5.3 in subfigure a visualizes scaled frequency distributions about number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts, and in subfigure b visualizes correlation between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts.

Table 5.4 illustrates how comparison of connectivity between 102 core concepts in collection of concept maps drawn by students and in article collection of the Wikipedia needs to address the fact that some parts of these collections are not overlapping and thus are not directly comparable. In addition, in this comparison it needs to be noted that inherently the relationships in concept maps drawn by students do not have specified pointing direction whereas hyperlinks in the Wikipedia have a specified pointing direction. Also please note that in further analysis about concept maps we consider only relationships mentioned by at least two students (based on 145 core relationships shown in Table 3.9).

Based on five comparison tests shown in Table 5.3 and visualization of Figure 5.3 it can be seen that the number of unique start/end concepts in hyperlinks of the Wikipedia and in relationships of concept maps for each of 102 core concepts is not following a

symmetric parallel decreasing trend. Instead it seems that concepts having high level of occurrences in the Wikipedia are largely different than those concepts getting high level of occurrences in concept maps.

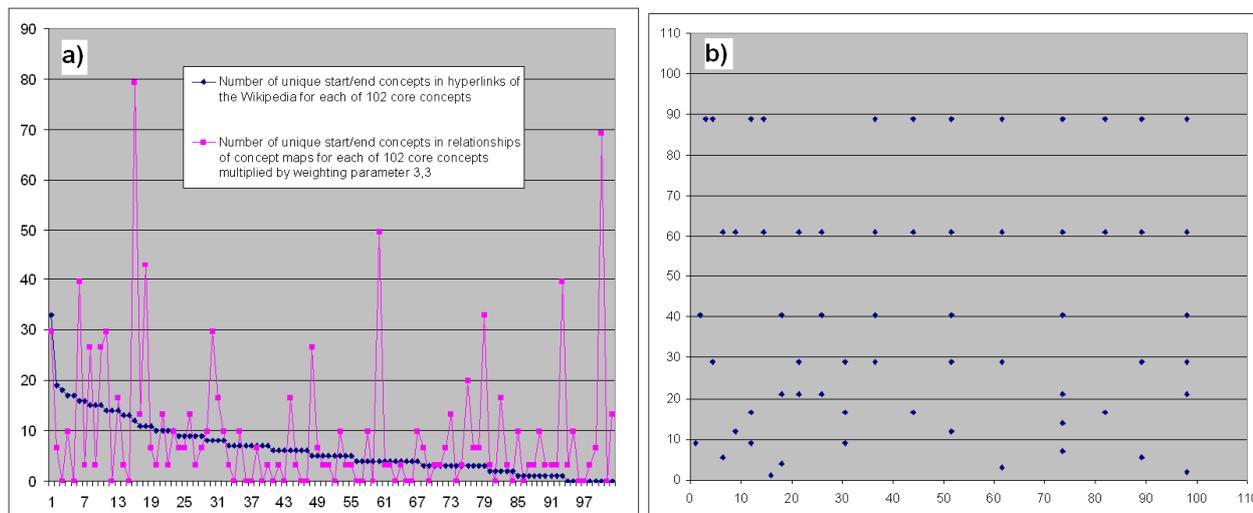


Figure 5.3. a) Scaled frequency distributions about number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in relationships of concept maps for each of 102 core concepts. Frequencies are shown so that along x axis the 102 core concepts are listed in decreasing order in respect to number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (i.e. core concepts are listed always in same ordering). b) Visualization of correlations between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (x) and number of unique start/end concepts in relationships of concept maps for each of 102 core concepts (y).

Table 5.4. Connectivity between 102 core concepts in collection of concept maps drawn by students (n=103) and in article collection of the Wikipedia (considering in concept maps only relationships mentioned by at least two students).

<i>Description of measured value</i>	<i>In collection of concept maps drawn by students</i>	<i>In article collection of the Wikipedia</i>
Number of unique relationships/hyperlinks between 102 core concepts	145 (relationships)	422 (hyperlinks)
- number of distinct concepts in relationships of concept maps and in hyperlinks of the Wikipedia	75	93
- number of shared concepts, i.e. number of overlapping distinct concepts in relationships of concept maps and in hyperlinks of the Wikipedia	69	69
Number of relationships/hyperlinks between shared concepts	113 (relationships), containing 64 unique concepts	248 (hyperlinks), containing 67 unique concepts
- number of shared relationships, i.e. number of overlapping relationships/hyperlinks concerning shared concepts	44 relationships	65 hyperlinks (42 of these hyperlinks have another hyperlink going into opposite direction)
- number of distinct concepts in shared relationships	43	43

As discussed already earlier in text before Table 3.9, there are *145 core relationships* connecting *102 core concepts* in concept maps drawn by students and these relationships – each mentioned by at least two students – use only 75 concepts of 102

core concepts (75 of 102 core concepts if word “brother” can be seen representing word “sister” since in the Wikipedia concept Sibling represents both concept Brother and concept Sister)¹³. Since concepts “cloth” (corresponds to Clothing) and “shoe” remain outside otherwise interconnected entity, these two concepts are excluded and we use in further analysis only 73 concepts concerning connectivity in the concept maps.

Relying on last edited versions of articles and hyperlinks by date 3 March 2008 in the Wikipedia, we found altogether 422 *hyperlinks* in the Wikipedia between 102 core concepts, shown in Appendix I. 192 of these 422 hyperlinks had an hyperlink going to opposite direction, and 230 of these 422 hyperlinks did not have a hyperlink going to opposite direction. In these 422 hyperlinks in the Wikipedia connecting 102 core concepts we identified 93 distinct concepts of 102 core concepts¹⁴. Since concepts Dream and Bed remain outside otherwise interconnected entity, these two concepts are excluded and we use in further analysis only 91 concepts concerning connectivity in the Wikipedia.

Among 102 core concepts, when considering number of overlapping distinct concepts in relationships of concept maps (considering only relationships mentioned by at least two students, based on 145 core relationships shown in Table 3.9) and hyperlinks of the Wikipedia, we identified 69 *shared concepts*. Based on Appendix H showing how each of 102 core concepts is connected to other concepts belonging to 102 core concepts—both in the Wikipedia and in concept maps—we generated Table 5.5 to show a comparison of these two connectivities among just a subset of 69 shared concepts. Thus Table 5.5 shows for both the Wikipedia and concept maps 69 shared concepts in descending ranking in respect to appearing as either start or end concept among 102 core concepts either in hyperlinks of the Wikipedia or in relationships of concept maps respectively.

Based on Table 5.5 for each of five comparison tests Table 5.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts and the number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts.

¹³ Thus in connectivity concerning concept maps there is absence of 27 of 102 core concepts: “baby” (corresponds to Infant), “bed”, “bread”, “childhood”, “city”, “eating”, “evolution”, “exam” (corresponds to Test_(assessment)), “flower”, “forest”, “fun”, “future”, “goal_(to_achieve)”, “goodness”, “hate” (corresponds to Hatred), “marriage”, “paper”, “pen”, “people”, “philosophy”, “pleasure”, “rain”, “sadness”, “sport”, “succeeding” (corresponds to Management), “time” and “world”.

¹⁴ Thus in connectivity concerning the Wikipedia there is absence of 9 of 102 core concepts: Chair, Environment, Fun, Goodness, Growing, Holiday, Living, Management and Study.

Table 5.5 part 1 of 2 (starts here and continues on next page). Comparison between conceptual networks of concept maps generated by students (n=103) and hyperlink network of corresponding Wikipedia articles when analysing 69 shared concepts.

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Concept</i>	<i>Occurrences as start or end concept in relationships between concepts</i>	<i>Ranking</i>	<i>Concept</i>	<i>Occurrences as start or end concept in hyperlinks between concepts</i>	<i>Ranking (how many positions higher than ranking of concept maps drawn by students)</i>
family	24	1	Human	33	1 (+7s)
friend	15	2	Plant	19	2 (+35s)
nature	13	3	Education	17	3 (+23.5s)
love	12	4.5s	Love	16	4.5s (0s)
work	12	4.5s	Oxygen	16	4.5s (+51.5s)
school	10	6	Animal	15	7s (+4s)
death	9	8s	Religion	15	7s (+49s)
health	9	8s	Water	15	7s (+4s)
human	9	8s	Death	14	9.5s (-1.5s)
animal	8	11s	Food	14	9.5s (+6s)
birth	8	11s	Biology	13	11 (+45s)
water	8	11s	Family	12	12 (-11)
home	6	13	Leisure (corresponds to "freetime")	11	14s (+5.5s)
food	5	15.5s	Nature	11	14s (-11s)
hobby	5	15.5s	Organism	11	14s (+23s)
house	5	15.5s	Adolescence (corresponds to "young_(person)")	10	17.5s (+38.5s)
joy	5	15.5s	Child	10	17.5s (+2s)
child	4	19.5s	Emotion	10	17.5s (+38.5s)
dog	4	19.5s	Television	10	17.5s (+9s)
freetime	4	19.5s	Atmosphere_of_Earth (corresponds to "air")	9	22s (+15s)
mother	4	19.5s	God	9	22s (+15s)
computer	3	26.5s	Mother	9	22s (-2.5s)
education	3	26.5s	Music	9	22s (+34s)
father	3	26.5s	Sibling (corresponds to "sister")	9	22s (+15s)
ground	3	26.5s	Happiness	8	26.5s (0s)
happiness	3	26.5s	Health	8	26.5s (-18.5s)
pet	3	26.5s	Hobby	8	26.5s (-11s)
sorrow	3	26.5s	Sun	8	26.5s (0s)
sun	3	26.5s	Diet_(nutrition) (corresponds to "nutriment")	7	30.5s (+25.5s)
television	3	26.5s	Father	7	30.5s (-4s)
tree	3	26.5s	Old_age (corresponds to "elderness")	7	30.5s (+6.5s)
air	2	37s	War	7	30.5s (+25.5s)
car	2	37s	Clothing (corresponds to "cloth")	6	34s (+22s)
clock	2	37s	House	6	34s (-18.5s)
disease	2	37s	Parent	6	34s (+22s)

Table 5.5 part 2 of 2 (started on previous page and continues here).

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Concept</i>	<i>Occurrences as start or end concept in relationships between concepts</i>	<i>Ranking</i>	<i>Concept</i>	<i>Occurrences as start or end concept in hyperlinks between concepts</i>	<i>Ranking (how many positions higher than ranking of concept maps drawn by students)</i>
elderness	2	37s	Birth	5	39s (-28s)
god	2	37s	Disease	5	39s (-2s)
money	2	37s	Experience	5	39s (+17s)
organism	2	37s	Learning	5	39s (+17s)
party	2	37s	Pet	5	39s (-12.5s)
plant	2	37s	Purpose	5	39s (+17s)
sister	2 ("brother")	37s	Teacher	5	39s (+17s)
biology	1	56s	Computer	4	45.5s (-19s)
book	1	56s	Friendship (corresponds to "friend")	4	45.5s (-43.5s)
cat	1	56s	Hospital	4	45.5s (+10.5s)
cloth	1	56s	Light	4	45.5s (+10.5s)
dream_(sleeping)	1	56s	Physical_fitness (corresponds to "physical_training")	4	45.5s (+10.5s)
emotion	1	56s	Tree	4	45.5s (-19s)
experience	1	56s	Automobile (corresponds to "car")	3	53.5s (-16.5s)
heart	1	56s	Book	3	53.5s (+2.5s)
hospital	1	56s	Cat	3	53.5s (+2.5s)
learning	1	56s	Clock	3	53.5s (-16.5s)
light	1	56s	Dog	3	53.5s (-34s)
music	1	56s	Heart	3	53.5s (+2.5s)
nutriment	1	56s	Home	3	53.5s (-40.5s)
oxygen	1	56s	Money	3	53.5s (-16.5s)
parent	1	56s	Party	3	53.5s (-16.5s)
peace	1	56s	School	3	53.5s (-47.5s)
phone	1	56s	Dream	2	60s (-4s)
physical_training	1	56s	Joy	2	60s (-44.5s)
purpose	1	56s	Peace	2	60s (-4s)
religion	1	56s	Ground	1	65.5s (-39s)
sea	1	56s	Sea	1	65.5s (-9.5s)
shoe	1	56s	Shoe	1	65.5s (-9.5s)
summer	1	56s	Sorrow	1	65.5s (-39s)
teacher	1	56s	Summer	1	65.5s (-9.5s)
travel	1	56s	Telephone (corresponds to "phone")	1	65.5s (-9.5s)
war	1	56s	Travel	1	65.5s (-9.5s)
young_(person)	1	56s	Work	1	65.5s (-61s)

To facilitate identifying possible similarities between frequency distributions of Table 5.5 we transformed for representation of Table 5.6 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of unique start/end concepts in in relationships of concept maps for each of 69 shared concepts has a weighting parameter 1 and scaled frequency distribution of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts has a weighting parameter 0.4. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.6. Degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts and the number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts (n=103).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of unique start/end concepts in in relationships of concept maps for each of 69 shared concepts (scaled)	number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.04895 (null hypothesis Hks rejected)	gamma=0.2460317 (standard error 0.1916975); null hypothesis Hgk not rejected (p=0.1993388)	rho=0.2746393; null hypothesis Hsr rejected (p=0.02239)	tau=0.213873; null hypothesis Hkr rejected (p=0.01925)

Based on Table 5.5 Figure 5.4 visualizes correlation between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia among 102 core concepts for each of 69 shared concepts and number of unique start/end concepts in in relationships of concept maps among 102 core concepts for each of 69 shared concepts.

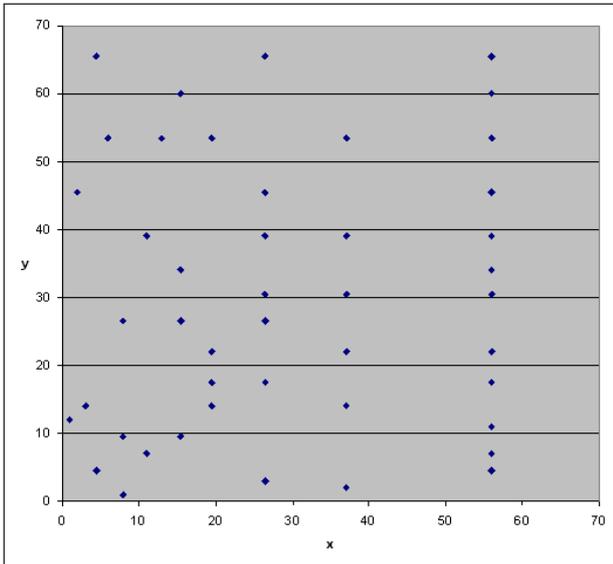


Figure 5.4. Visualization of correlation between ranking of concepts appearing as either start or end concept in relationships of concept maps drawn by students (x) (n=103) and ranking of concepts appearing as either start or end concept in hyperlinks of the Wikipedia (y), in respect to 69 shared concepts among 102 core concepts.

Furthermore based on Table 5.5 we generated Table 5.7 to show concepts having the greatest and smallest ranking difference when comparing occurrences as start or end concept among 102 core concepts for each of 69 shared concepts either in hyperlinks of the Wikipedia or in relationships of concept maps in respect to concepts more occurring in hyperlinks of the Wikipedia, concepts more occurring in concept maps, and concepts with the smallest difference when considering occurrences in concept maps minus occurrences in hyperlinks of the Wikipedia.

Based on Table 5.7 it seems that concepts occurring more as start/end concepts in the Wikipedia include more formal themes representing relatively high levels of classification (for example Oxygen, Religion, Biology, Adolescence and Emotion) whereas concepts occurring more as start/end concepts in the concept maps include less formal themes near a personal viewpoint (for example Work, School, Joy, Friendship and Home), and relatively neutral balancing between the Wikipedia and concept maps emerges with such central concepts as child, mother and father. Even if both Wikipedia and concept maps cover similar kind of topics they emphasize different themes so that for example concerning theme of emotions the Wikipedia emphasizes Emotion and Music, concept maps emphasize Joy and Sorrow, and neutral balancing emerges with Happiness and Love.

Table 5.7. Some of the greatest and smallest ranking differences for concepts in respect to occurrences as start/end concepts among 102 core concepts for each of 69 shared concepts in relationships of concept maps drawn by students versus occurrences as start/end concepts among 102 core concepts for each of 69 shared concepts in hyperlinks of the Wikipedia.

Some of the greatest ranking differences for concepts having higher ranking position for occurrences as start/end nodes in hyperlinks of the Wikipedia than in relationships of concept maps drawn by students		Some of the greatest ranking differences for concepts having lower ranking position for occurrences as start/end nodes in hyperlinks of the Wikipedia than in relationships of concept maps drawn by students		Some of the smallest ranking differences for concepts between ranking based on occurrences as start/end nodes in hyperlinks of the Wikipedia and in relationships of concept maps drawn by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Oxygen	+51.5s	Work	-61s	Happiness; Love; Sun	0s
Religion	+49s	School	-47.5s	Death	-1.5s
Biology	+45s	Joy	-44.5s	Child	+2s
Adolescence; Emotion	+38.5s	Friendship	-43.5s	Disease	-2s
Plant	+35s	Home	-40.5s	Book; Cat; Heart	+2.5s
Music	+34s	Ground; Sorrow	-39s	Mother	-2.5s
Diet_(nutrition); War	+25.5s	Dog	-34s	Animal; Water	+4s
Education	+23.5s	Birth	-28s	Dream; Father; Peace	-4s
Organism	+23s	Computer; Tree	-19s	Leisure	+5.5s

Table 5.8 shows how each of 69 shared concepts have been connected to other concepts inside collection of 69 shared concepts, both in Wikipedia and concept maps (considering in concept maps only relationships mentioned by at least two students). So while Table 5.5 and Table 5.7 show connectivity for 69 shared concepts among 102 core concepts now Table 5.8 shows connectivity for 69 shared concepts only among 69 shared concepts.

When considering connectivity between 69 shared concepts (i.e. from a concept belonging to 69 shared concepts to another concept belonging to 69 shared concepts), there are 248 hyperlinks in the Wikipedia, containing 67 unique concepts, and respectively there are 113 relationships in concept maps, containing 64 unique concepts (considering only relationships mentioned by at least two students). In 248 hyperlinks connecting 69 shared concepts in the Wikipedia, there are 114 hyperlinks that have a hyperlink going also into Wikipedia opposite direction inside 69 shared concepts.

Table 5.8 part 1 of 2 (starts here and continues on next page). Connectivity between 69 shared concepts in concept maps drawn by students (n=103) and in hyperlink network of the Wikipedia.

69 shared concepts	Conceptual network of concept maps drawn by students	Hyperlink network of the Wikipedia			
		Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Possibility to reach observed concept by surfing in hyperlink network connecting 69 shared concepts in the Wikipedia when starting from concepts Human ¹⁵
Adolescence (<i>young_ (person)</i>)	1	7	6	4	along link
Animal	7	12	9	8	along link
Atmosphere_of_Earth (<i>air</i>)	2	7	4	7	along link
Automobile (<i>car</i>)	2	2	2	1	along link
Biology	1	11	10	7	along link
Birth	6	5	1	4	along link
Book	1	2	1	1	against link
Cat	1	3	2	3	along link
Child	4	7	5	6	along link
Clock	2	1	0	1	against link
Clothing (<i>cloth</i>)	1	4	2	2	along link
Computer	3	4	2	2	along link
Death	8	11	5	8	along link
Diet_(nutrition) (<i>nutriment</i>)	1	7	5	4	along link
Disease	2	5	5	1	along link
Dog	4	3	2	3	along link
Dream	1	1	0	1	against link
Education	2	12	7	10	along link
Emotion	1	5	3	4	along link
Experience	1	2	2	0	along link
Family	21	11	11	5	along link
Father	3	6	5	5	along link
Food	4	12	3	10	along link
Friendship (<i>friend</i>)	13	3	1	3	along link
God	2	6	4	3	along link
Ground	3	0	0	0	not reachable
Happiness	3	5	5	2	along link
Health	9	7	6	5	along link
Heart	1	3	3	0	along link
Hobby	5	6	0	6	against link
Home	6	3	1	3	along link
Hospital	1	2	0	2	against link

¹⁵ Explanation for notations: along link = traversing along existing directions of hyperlinks is sufficient to reach observed concept when starting from concept Human; against link = traversing against existing directions of hyperlinks is needed; not reachable = observed concept is not reachable at all even if trying to proceed along and against existing directions of hyperlinks.

Table 5.8 part 2 of 2 (started on previous page and continues here).

69 shared concepts	Conceptual network of concept maps drawn by students		Hyperlink network of the Wikipedia			
	Number of unique start/end concepts in relationships for observed concept mentioned by at least two students in concept maps among 69 shared concepts	Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Possibility to reach observed concept by surfing in hyperlink network connecting 69 shared concepts in the Wikipedia when starting from concepts Human ¹⁶	
House	4	6	3	4	along link	
Human	8	25	11	16	along link	
Joy	4	2	2	1	along link	
Learning	1	4	2	3	along link	
Leisure (freetime)	4	8	5	5	along link	
Light	1	3	1	2	along link	
Love	11	11	7	6	along link	
Money	2	2	0	2	against link	
Mother	4	8	5	7	along link	
Music	0	5	3	2	along link	
Nature	11	9	5	8	along link	
Old_age (elderness)	2	5	3	4	along link	
Organism	1	9	8	3	along link	
Oxygen	1	12	10	6	along link	
Parent	1	6	4	6	along link	
Party	1	3	0	3	against link	
Peace	0	2	1	2	along link	
Pet	3	4	3	3	along link	
Physical_fitness (physical_training)	1	4	3	2	along link	
Plant	2	13	11	9	along link	
Purpose	0	2	0	2	against link	
Religion	0	8	7	3	along link	
School	8	3	3	2	along link	
Sea	1	1	1	1	along link	
Shoe	1	1	0	1	against link	
Sibling (sister/brother)	2	8	7	5	along link	
Sorrow	2	0	0	0	not reachable	
Summer	1	1	0	1	against link	
Sun	2	7	6	2	along link	
Teacher	1	3	2	3	along link	
Telephone (phone)	1	1	1	0	along link	
Television	3	8	8	0	along link	
Travel	0	1	1	0	along link	
Tree	3	3	1	2	along link	
War	1	6	4	3	along link	
Water	7	12	7	8	along link	
Work	9	1	1	0	along link	

¹⁶ Explanation for notations: along link = traversing along existing directions of hyperlinks is sufficient to reach observed concept when starting from concept Human; against link = traversing against existing directions of hyperlinks is needed; not reachable = observed concept is not reachable at all even if trying to proceed along and against existing directions of hyperlinks.

When considering overlap in connectivity between 69 shared concepts both in the Wikipedia and in concept maps (considering only relationships mentioned by at least two students) this overlap contains altogether 44 relationships of concept maps and 65 hyperlinks of the Wikipedia (42 of these hyperlinks have another hyperlink going into opposite direction). These 44 relationships and 65 hyperlinks contain 43 unique concepts. This seems to indicate that even if we started analysis with a collection of 102 inter-linked concepts generated by students it turns out that comparison to hyperlinks between corresponding Wikipedia articles brings available set of concepts having shared linkage to a reduced number of 43 concepts meaning about 42 percent of originally observed 102 concepts.

Please note that to keep notation relatively compact in further analysis we often compare concepts of the Wikipedia and concepts gained from students through word lists or concept maps so that we write concepts using only that form which is used in the Wikipedia. Thus even if actually making comparison between occurrences of concept “friend” in word lists or concept maps of students and occurrences of concept Friendship in the Wikipedia we often refer to them both with just notation Friendship (as shown for example in Table 5.9 and Figure 5.5).

Table 5.9. Overlap in connectivity between 69 shared concepts in concept maps drawn by students (n=103) and Wikipedia thus showing 44 shared links (shared by both the Wikipedia and concept maps, considering only relationships mentioned by at least two students). In concept maps there is a relationship between each pair of concepts (direction of conceptual relationships in concept maps are not specified) and in hyperlinks of the Wikipedia there is unidirectional linking (marked with ->) or bidirectional linking (marked with <->) between each pair of concept.

<i>Pair of concepts and their linking in the Wikipedia</i>	<i>Pair of concepts and their linking in the Wikipedia (continued)</i>
Animal <-> Human	Friendship <-> Love
Animal <-> Nature	Health -> Disease
Biology <-> Nature	Health <-> Physical_fitness
Birth -> Death	Hobby -> Leisure
Cat <-> Dog	Home -> Family
Child <-> Family	Home <-> House
Clock -> Computer	House -> Family
Computer -> Television	Human -> Family
Death <-> Disease	Human -> Love
Death -> Human	Leisure -> Television
Death -> War	Love -> Family
Dog <-> Pet	Love -> Happiness
Education <-> School	Mother -> Love
Emotion <-> Love	Nature -> Human
Family <-> Father	Nature <-> Plant
Family <-> Mother	Nature -> Sun
Family <-> Sibling	Old_age -> Death
Father <-> Mother	Oxygen <-> Water
Food -> Animal	Plant -> Tree
Food <-> Health	School <-> Teacher
Food -> Water	Sea <-> Water
Friendship -> Adolescence	Shoe -> Clothing
<i>(listing continues on column 2)</i>	

Table 5.9 and Figure 5.5 show the overlap in connectivity between 69 shared concepts. When comparing Figure 3.3 containing 74 interconnected concepts (73 concepts plus an

additional concept brother) with Figure 5.5 it appears that both these figures share several actively connected concepts (for example Family and Human) but some of the actively connected concepts of former figure are missing in latter figure (for example Work). In this publication we use notation conceptA->conceptB (i.e. two concepts separated with an arrow containing consecutive symbols of hyphen and greater-than sign or less-than sign) to represent directional links, hyperlinks or traversals from one concept to another concept.

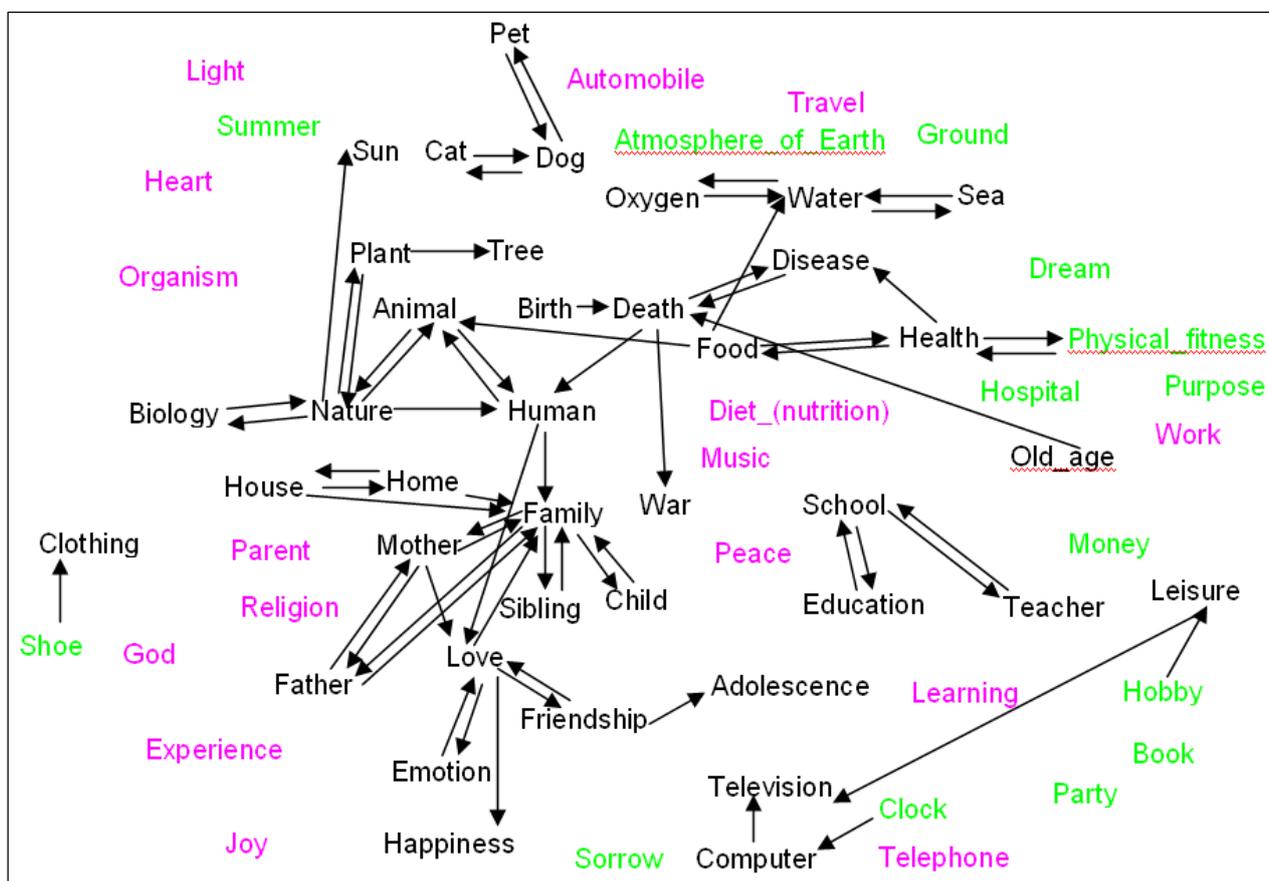


Figure 5.5. Black arrows show overlapping connectivity between 69 shared concepts in concept maps drawn by students (n=103) and the Wikipedia thus showing 44 shared links (shared by both the Wikipedia and concept maps, considering only relationships mentioned by at least two students) connecting 43 concepts. Formation of “hyperlink network of 55 concepts” for exploration experiments originated with all 69 concepts but those concepts that we decided to exclude are shown with green font and thus concepts with black and pink font are all concepts included in “hyperlink network of 55 concepts”. Black arrows indicate linking direction only in the Wikipedia since directions of conceptual relationships in concept maps are not specified.

In 113 relationships in concept maps connecting 69 shared concepts (considering only relationships mentioned by at least two students), there are 69 relationships that are not shared with the Wikipedia (as mentioned in Table 5.4). Among these non-shared 69 relationships the most frequently mentioned five relationships, based on frequencies shown in Table 3.9, are family↔friendship (15), friendship↔school (10), school↔work (9), joy↔sorrow (7) and friendship↔hobby (6), so thus we think that even if connectivity between these concepts seems to have been considered important for students in their concept maps, their corresponding connectivity has not however emerged into hyperlink network of the Wikipedia during its collaborative building process.

We wanted to get better understanding about how students in a real educational setting traverse intuitively in hyperlink network of the Wikipedia and we wanted to try to identify some typical characteristics in associative conceptual chains in exploration paths. To carry out exploration experiment with students in such a hyperlink network that has a sufficient coverage and compactness and that can be conveniently contrasted to our other experimental data about conceptual learning we decided to use such partial segment of the hyperlink network of the Wikipedia that relies on 69 shared concepts.

To ensure comparability of various exploration paths we decided that all exploration paths had to start from concept Human since among 69 shared concepts in hyperlink network of the Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5. It turned out that among 69 shared concepts only 57 concepts remained reachable from concept Human (with one or more intermediate hyperlinks needed to be traversed) if each hyperlink was allowed to be traversed only along its actual traversal direction. Thus twelve concepts had to be excluded from analysis, including Book, Clock, Dream, Ground, Hobby, Hospital, Money, Party, Purpose, Shoe, Sorrow and Summer as well as 20 hyperlinks containing any of these 12 concepts. Since we considered that Atmosphere_of_Earth and Physical_fitness seemed to have some terminological ambiguity, we removed these two concepts from the hyperlink network of 69 shared concepts as well as 16 hyperlinks containing either of these two concepts (11 for Atmosphere_of_Earth and 5 for Physical_fitness). Therefore finally, in *exploration experiment* the students were allowed to browse inside a hyperlink network containing 55 concepts and 212 hyperlinks between them, and we refer to this network in our further analysis with name “*hyperlink network of 55 concepts*”. All these 212 hyperlinks of “hyperlink network of 55 concepts” are connecting 55 concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (55 concepts include concept Human). All these 212 hyperlinks are shown in Appendix J supplied with a relation statement for each hyperlink in English and its Finnish translation.

Relation statements have been extracted from Wikipedia article of start concept, primarily taken from the text surrounding hyperlink anchor of the currently observed hyperlink pointing to end concept, but possibly with some modifications. In relation statements start concept and end concept can be in various conjugated forms and thus not necessarily as nouns although a noun form can be considered preferable in most cases for clarity. Please note that due to lack of suitable phrase surrounding hyperlink anchor of start concept of hyperlink some of the relation statements are generated and synthesized based on other contextual text segments we identified relatively near the hyperlink anchor or possibly based on relation statement we managed to identify for another hyperlink going into opposite direction (i.e. for a hyperlink whose start concept is end concept of current hyperlink and end concept is start concept of current hyperlink). In Appendix J it is mentioned which relation statements have been generated and synthesized with this special method.

We carried out in “hyperlink network of 55 concepts” an *exploration task* with 49 students having an average age of 17.4 years (median value 17). In further analysis (see Subchapter 10.1) we refer to this group of students as experiment group (n=49) and full

listing of background characteristics of members of experiment group are shown in Appendix X. Appendix Y lists for each member of this experiment group concepts actively selected by student during exploration task. Although we present here the results in English, the exploration task was carried out in Finnish based on Finnish translations of all 212 hyperlinks shown in Appendix J supplied with a relation statement for each hyperlink. An important characteristic to note is that in exploration experiment each student had to traverse exactly twenty hyperlinks (i.e. to take 20 steps) in “hyperlink network of 55 concepts” and for each student each hyperlink belonging to “hyperlink network of 55 concepts” was allowed to be traversed at most once. So when starting exploration task the student had 212 different hyperlinks available to be traversed at some point of experiment but always when traversing any hyperlink in the “hyperlink network of 55 concepts” this traversed hyperlink was removed from the original collection of available hyperlinks thus reducing traversable hyperlinks one by one. Thus even if the student’s exploration path leads to an already earlier visited concept in the “hyperlink network of 55 concepts” this concept no longer shows those hyperlinks that the student has already traversed when departing this concept earlier in exploration. However, an exceptional case is if the student’s exploration reaches a dead-end, i.e. the student arrives to a concept that does not offer (at least anymore) any departing hyperlinks to be traversed next, and in this case the student is exceptionally provided with a sufficient series of non-branching hyperlinks that enable her to *roll back exploration* to the most previous point in her exploration path history that still offers traversable departing hyperlinks. There are altogether 14 roll back hyperlinks (shown in Appendix J) that supplement 212 hyperlinks of “hyperlink network of 55 concepts”. Table 5.10 illustrates an example of three consecutive steps of exploration in “hyperlink network of 55 concepts” when a student performs exploration task.

Appendix K shows the number of traversals made by students for some of the highest-ranking traversed hyperlinks in this network of 212 hyperlinks, number of traversals are shown for all students (n=49) and also separately for male students (n=18) and female students (n=31). Appendix K also shows how many alternative hyperlinks were available when the student decided to select each hyperlink. 164 hyperlinks of these 212 available hyperlinks (164/212 is about 0.774 thus meaning about 77.4 percent) became explored by students in exploration task starting from concept Human. There were five concepts of 55 concepts that did get during exploration zero departures and zero arrivals (Cat, Computer, Dog, Pet and Telephone).

Among these 164 explored hyperlinks some of the *most actively traversed hyperlinks* are shown in Table 5.11. In the table the number of traversals for such hyperlinks that depart from concept Human can be influenced by the fact that in the exploration experiment students had to start always from concept Human, however in parenthesis is shown the number of traversals when excluding those traversals that happened during starting from concept Human. Table 5.11 also shows for each hyperlink the average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink (for hyperlinks departing from concept Human, indicated with an asterisk (*), the average number of selectable alternative hyperlinks is calculated only based on

those traversals when excluding starting from concept Human). Showing this average number of selectable alternative hyperlinks aims to offer a some kind of possibility to judge if a high number of traversals for a hyperlink is related to having a small number of selectable hyperlinks in traversals just preceding traversing current hyperlink which could indicate that popularity of current hyperlink can be induced by some kind of bottleneck and not so much motivated by active selections by student. Thus for example even if hyperlink Emotion->Love has got the second-highest-ranking position in Table 5.11 with 26 traversals among all students it turns out that relatively low value of the average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink (1.846154) seem to indicate that the popularity of traversing hyperlink Emotion->Love might be partly contributed by limited number of alternative paths available before arriving to concept Emotion.

Table 5.10. Illustration of an example of three consecutive steps of exploration in “hyperlink network of 55 concepts” when student performs exploration task. This sample is based on full listing of hyperlinks shown in Appendix J.

<p>Step 1. <i>Student has arrived to concept Friendship and three hyperlinked concepts, indicated here with underlining, are shown supplied with following relation statements in which the current concept is indicated with cursive formatting:</i></p> <ul style="list-style-type: none"> - <i>friendships</i> are often the most important human relationships of the emotional life in <u>adolescence</u> - in interpersonal relationships <i>friendships</i> are found also among <u>animals</u> with high intelligence - concerning <i>friendship</i> <u>love</u> is above all other motives as an inspiration <p><i>Student decides to traverse hyperlink leading to Love.</i></p>
<p>Step 2. <i>Student has arrived to concept Love and six hyperlinked concepts are shown supplied with following relation statements:</i></p> <ul style="list-style-type: none"> - according to <u>biology</u> there are two major drives in <i>love</i>: sexual attraction and attachment - <i>love</i> can describe an intense feeling of affection, an <u>emotion</u> or an emotional state - <i>love</i> has many different meanings ranging to something one would die for, like <u>family</u> - concerning <i>love</i> <u>friendship</u> means the spirit between friends - <i>love</i> is connected to emotions about <u>happiness</u> - throughout history, philosophy and <u>religion</u> have done the most speculation on the phenomenon of <i>love</i> <p><i>Student decides to traverse hyperlink leading to Friendship.</i></p>
<p>Step 3. <i>Student has arrived again to concept Friendship and now two hyperlinked concepts are shown supplied with following relation statements, i.e. hyperlink to Love traversed last time is not anymore traversable and has been removed:</i></p> <ul style="list-style-type: none"> - <i>friendships</i> are often the most important human relationships of the emotional life in <u>adolescence</u> - in interpersonal relationships <i>friendships</i> are found also among <u>animals</u> with high intelligence <p><i>Student decides to traverse hyperlink leading to Adolescence, etc.</i></p>

Table 5.11. Some of the highest-ranking traversed hyperlinks in “hyperlink network of 55 concepts” in exploration paths of students (n=49), shown for all students and also separately for male students and female students (full listing is available in Appendix K).

<i>All students participating in exploration task (n = 49)</i>			<i>All male students participating in exploration task (n = 18)</i>		<i>All female students participating in exploration task (n = 31)</i>	
<i>Traversed hyperlink (current hyperlink)</i>	<i>Number of traversals</i>	<i>Average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>
Happiness -> Emotion	29	3.758621	Animal -> Nature	4	Happiness -> Emotion	25
Emotion -> Love	26	1.846154	Joy -> Happiness	4	Emotion -> Love	23
Joy -> Happiness	24	2.125	Happiness -> Joy	4	Disease -> Death	22
Disease -> Death	24	4.625	Happiness -> Emotion	4	Joy -> Happiness	20
Happiness -> Joy	21	4.285714	Sun -> Oxygen	3	Adolescence -> Education	17
Human -> Diet_(nutrition)	19 (2*)	5.5*	Sun -> Plant	3	Happiness -> Joy	17
Emotion -> Experience	19	7.263158	Biology -> Animal	3	Human -> Diet_(nutrition)	16
Experience -> Emotion (only to roll back)	18	3.833333	Organism -> Biology	3	Emotion -> Experience	16
Organism -> Biology	17	5.176471	Organism -> Plant	3	Experience -> Emotion (only to roll back)	15
Adolescence -> Education	17	6.764706	Organism -> Heart	3	Organism -> Biology	14
Love -> Friendship	16	2.75	Oxygen -> Sun	3	Education -> Learning	14
Education -> Learning	14	3.428571	Oxygen -> Plant	3	Learning -> Education	14
Learning -> Education	14	5.642857	Oxygen -> Water	3	Love -> Friendship	14
Emotion -> Happiness	14	3.571429	Human -> Diet_(nutrition)	3	Family -> Mother	12
Family -> Mother	13	8.384615	Plant -> Nature	3	Health -> Disease	12
Diet_(nutrition) -> Health	13	14.92308	Plant -> Tree	3	Diet_(nutrition) -> Health	11
Health -> Disease	13	10.38462	Experience -> Emotion (only to roll back)	3	Emotion -> Happiness	11
Love -> Happiness	11	6.363636	Happiness -> Love (only to roll back)	3	Emotion -> Joy	10
Emotion -> Joy	11	2.090909	Love -> Happiness	3	Friendship -> Adolescence	10
Love -> Emotion	10	5.4	Emotion -> Experience	3	Biology -> Nature	9
Friendship -> Adolescence	10	5.3	Emotion -> Happiness	3	Human -> Adolescence	9
			Emotion -> Love	3	Adolescence -> Child	9
					Love -> Emotion	9

Besides 212 above mentioned hyperlinks the students were allowed to explore still additional 14 hyperlinks that were traversed to roll back to previously visited concept when the student's exploration had led to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration. Among these 14 additional hyperlinks, which are shown in Appendix J, three most actively traversed ones by all students were: Experience -> Emotion (18 traversals), Experience -> Learning (8 traversals) and Joy -> Emotion (7 traversals).

Appendix L shows, based on Appendix K, the most actively traversed departing and arriving hyperlinks for each of 55 concepts in "hyperlink network of 55 concepts". Relying on Appendix L Figure 5.6 visualizes the most actively traversed departing and arriving hyperlinks in "hyperlink network of 55 concepts".

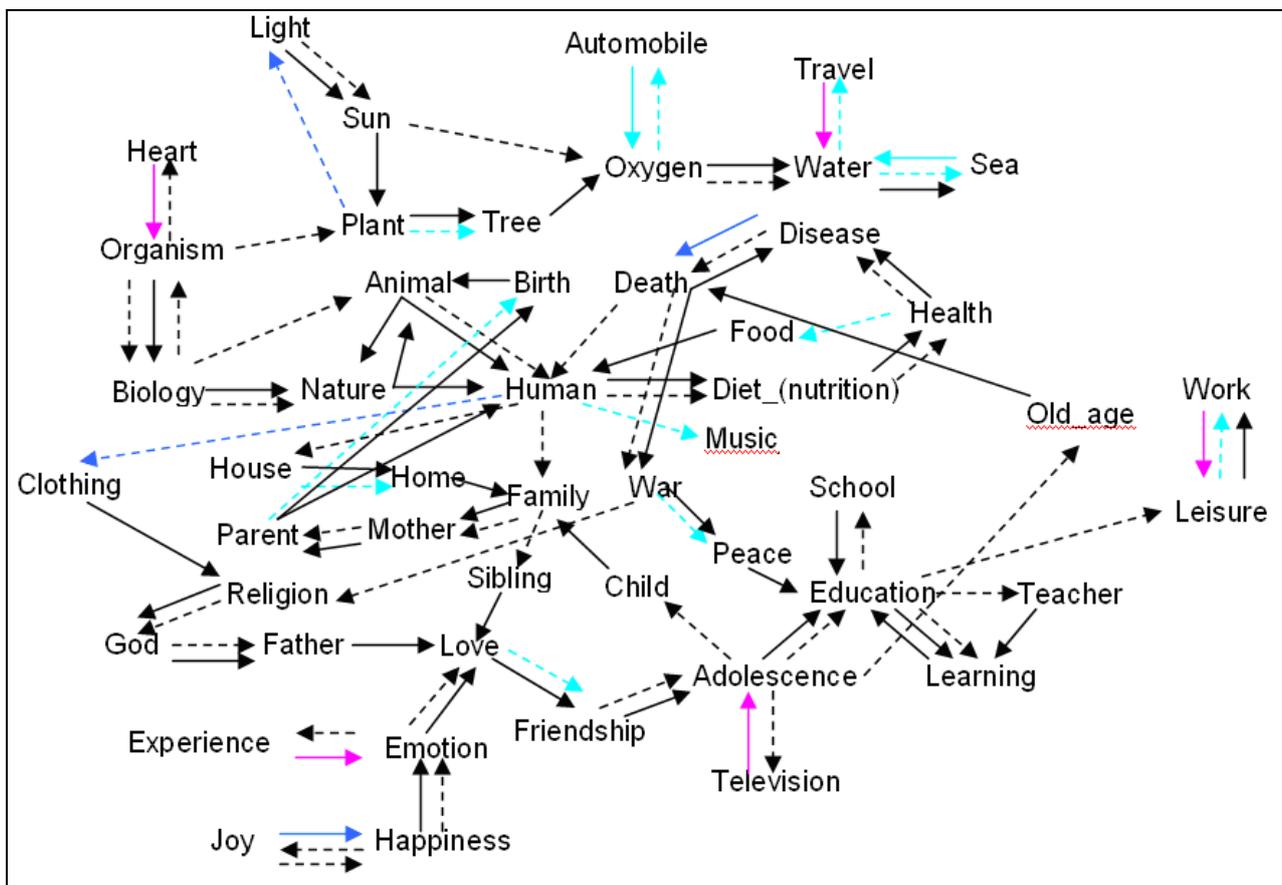


Figure 5.6. The most actively traversed departing and arriving links in "hyperlink network of 55 concepts" are illustrated so that solid lines indicate departing links and dotted lines arriving links (n=49). If several links share the position as the most active link they all are included in the figure as parallel links (for example both links Animal->Human and Death->Human arrive at concept Human). Five links having pink color indicate traversed links that are not in original "hyperlink network of 55 concepts" but are needed to roll back in case of encountering a dead end in exploration. Turquoise and blue lines indicate that surfing occurred along the sole connecting arriving/departing link between these two concepts (i.e. no alternative routes were available), turquoise links were inherently sole connecting links whereas blue links emerged as sole connecting links after roll back links had been excluded between these two concepts. Among all 55 concepts five concepts did not have any traversed arriving/departing linking, including Cat, Computer, Dog, Pet and Telephone, and concept Music had only traversed arriving link and not departing link.

Table 5.12 shows in "hyperlink of 55 concepts" for each concept the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths so that occurrences are counted separately for traversed hyperlinks and departures from a concept.

We think that various forms of interactive and engaging learning activities can be developed based student's exploration in hyperlink network. To illustrate pedagogic potential of *associative chaining* of browsed concepts and relation statements in exploration paths we generated examples based on Figure 5.6. An exploration path starting from concept Human and proceeding the *most actively traversed departing hyperlinks* in "hyperlink network of 55 concepts" generates following *learning path*:

Human->Diet_(nutrition)->Health->Disease->Death->War->Peace->Education->Learning->Education (and then remaining in an eternal cycle Education->Learning->Education->etc.)

When chaining relation statements of each of these hyperlinks (shown in Appendix J) we gain a following *educational story* (start concept of hyperlink indicated with italics and end concept of hyperlink with underlining)¹⁷:

Concerning *humans* body size is significantly influenced by environmental factors such as diet.
Dietary habits and choices play a significant role in health.
Health is a state of complete well-being and not merely the absence of disease.
Disease is often used to refer to a uncomfortable condition possibly leading to death.
War can be considered as a situation whereby *death* assumes absolute value.
Theories of *war* must explain also peace.
Peaceful development can be a set of many different elements such as education.
Education encompasses teaching and learning specific skills.
Learning is the goal of education.

We think that even if having somewhat limited scope, already these examples show that suggested method of traversing exploration paths can offer to the student a relatively intuitive way to adopt step by step new pieces of knowledge in a simple process. Relying on exploration experiment with 49 students this exploration path can be considered to represent some kind of average association chain of students about gradually evolving thinking when starting from concept Human and finally reaching limits of this expansion when arriving to a repeating cycle. We believe that with sufficiently large and diverse collection of traversed exploration paths a student can achieve relatively extensive coverage of hyperlink network of concepts about desired learning topic. We think that this gained collection of exploration paths can offer interesting insight to the student's conceptualization and personal characteristics as well as to the semantical properties of language and consciousness.

¹⁷ In the shown educational story the relation statements for hyperlinks Diet->Health and Peace->Education illustrate that in relation statements start concept and end concept can be in various conjugated forms.

Table 5.12. In "hyperlink of 55 concepts" for each concept the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths so that occurrences are counted separately for traversed hyperlinks and departures from a concept.

55 concepts reachable in exploration from concept Human in "hyperlink network of 55 concepts"	In "hyperlink network of 55 concepts" (belonging to hyperlink network of the Wikipedia)		In exploration paths that students (n=49) traverse in "hyperlink network of 55 concepts" (belonging to hyperlink network of the Wikipedia)			
	Current concept	as a start concept for how many hyperlinks	as an end concept for how many hyperlinks	as a start concept for how many traversed hyperlinks	as an end concept for how many traversed hyperlinks	in exploration how many departures from this concept
Adolescence	4	6	4	5	33	31
Animal	7	8	5	6	18	19
Automobile	1	1	1	1	2	2
Biology	6	9	6	6	32	33
Birth	4	1	3	1	5	5
Cat	3	2	0	0	0	0
Child	6	5	5	3	17	17
Clothing	2	1	2	1	3	3
Computer	2	1	0	0	0	0
Death	7	5	6	4	35	31
Diet (nutrition)	4	4	4	2	23	23
Disease	1	4	1	4	24	27
Dog	3	2	0	0	0	0
Education	10	6	8	6	45	46
Emotion	4	3	4	3	70	48
Experience	0	2	0	2	0	27
Family	5	10	5	8	34	35
Father	5	5	5	4	12	13
Food	10	1	1	1	1	1
Friendship	3	1	3	1	14	16
God	3	2	1	1	5	5
Happiness	2	4	2	4	50	55
Health	4	4	4	3	23	23
Heart	0	3	0	3	0	15
Home	3	1	1	1	2	2
House	4	2	1	1	2	2
Human	16	11	14	9	80	36
Joy	1	2	1	2	24	32
Learning	2	2	2	2	22	20
Leisure	5	4	5	3	14	11
Light	2	1	2	1	7	6
Love	6	7	5	6	50	48
Mother	7	5	4	4	17	17
Music	2	1	0	1	0	1
Nature	7	4	6	3	20	21
Old_age	4	3	2	2	4	5
Organism	3	7	3	6	34	29
Oxygen	6	9	6	9	26	26
Parent	6	4	6	4	17	17
Peace	2	1	2	1	8	8
Pet	3	3	0	0	0	0
Plant	8	8	8	6	31	32
Religion	3	7	3	4	10	10
School	2	3	2	2	10	11
Sea	1	1	1	1	7	7
Sibling	5	7	3	5	12	13
Sun	2	6	2	5	14	17
Teacher	3	2	3	2	12	9
Telephone	0	1	0	0	0	0
Television	0	7	0	4	0	7
Travel	0	1	0	1	0	3
Tree	2	1	2	1	7	7
War	3	4	3	3	15	15
Water	8	6	7	5	23	22
Work	0	1	0	1	0	5
<i>Sum</i>	212	212	164	164	914	914
<i>Average</i>	3.85	3.85	2.98	2.98	16.62	16.62
<i>Median</i>	3	3	2	3	12	15

We think that in hyperlink network those concepts that belong to repeating cycle that define limits to expansion of exploration path may indicate some essential properties about semantics and how conceptualization inherently emerges in human mind. Since our research focuses on education and learning we find it fascinating that just shown example of exploration path starting from concept Human happens to finally arrive to a repeating cycle that contains concepts Education and Learning. Also in our later analysis discussed in Subchapter 6.3 we encountered similar feature of arriving to a repeating cycle. We suggest that this process of arriving to a repeating cycle that we have identified in the Wikipedia (which holds small-world properties (Ingawale et al. 2009)) is related to previous findings of Kinouchi et al. (Kinouchi et al. 2002) that a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step). Naturally it can be possible to purposefully avoid entering an eternal cycle in exploration so that when arriving again to a previously visited concept now the learner chooses the second-highest-ranking concept (if available) instead of the highest-ranking concept to proceed next and thus a new branching emerges to traversed path enabling continuing exploration along yet unexplored hyperlinks.

Different perspectives can be achieved if exploration path proceeds a chain of arriving links instead of departing links. An exploration path starting from concept Human and proceeding the *most actively traversed arriving hyperlinks* in “hyperlink network of 55 concepts” generates two alternative *learning paths* since it appears that there are two most actively traversed arriving links arriving to concept Human that share the highest ranking and thus two different paths emerge proceeding to Death or Animal.

One of these two paths is:

Human<-Death<-Disease<-Health<-Diet_(nutrition)<-Human (and then again possibility to proceed to Death or Animal, i.e. leading to consecutive cycles that arrive back to Human or then leading to a path proceeding through concept Animal as explained next)

The other one of two paths is:

Human<-Animal<-Biology<-Organism<-Biology (and then remaining in an eternal cycle Biology<-Organism<-Biology <-etc.)

These just shown learning paths can be contrasted with a learning path generated based on the highest-ranking relationships in concept maps drawn by students (n=103) mentioned by at least two students (based on Table 3.9) and considering only those relationships that contain concepts belonging to 55 concepts of “hyperlink network of 55 concepts”. When traversing *relationships of concept maps* (linking direction was not specified in relationships of concept maps) so that we start from concept “human” and

proceed at each step to relationship that has highest number of occurrences we get a learning path:

human↔family↔friend↔school↔work↔education↔school (and then again possibility to proceed to work and so on thus forming an eternal cycle)

When comparing learning path generated based on relationships of concept maps with learning path generated based on “hyperlink network of 55 concepts” it seems that learning path based on relationships of concept maps focuses on social themes whereas learning path based on “hyperlink network of 55 concepts” focuses on survival themes. Anyway, interestingly both learning paths finally arrive to an eternal cycle having a shared theme concerning education. Further experiments with much bigger samples are needed to make more accurate estimates.

In respect to traversing exploration paths in networks shown in Figure 5.6 it could be also possible to select paths so that highest-ranking concept based on various properties (for example the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths, as shown in Table 5.12) could be prioritized even when having distance longer than just one hyperlink. Therefore each concept could be considered metaphorically to have some kind of own gravitational field and the sum of all these gravitational fields would then contribute to selecting at each step the next hyperlink to be traversed next in the hyperlink network.

5.4. Comparison between patterns of exploration and structure of hyperlink network

Based on Table 5.12 for each of five comparison tests Table 5.13 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts”.

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.13 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of departures from a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.5. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.13. Degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of departures from a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.3233 (null hypothesis Hks not rejected)	gamma=0.4839216 (standard error 0.1817563); null hypothesis Hgk rejected (p=0.007756853)	rho=0.5741486; null hypothesis Hsr rejected (p=4.581×10 ⁻⁶)	tau=0.4512068; null hypothesis Hkr rejected (p=5.481×10 ⁻⁶)

Based on Table 5.12 for each of five comparison tests Table 5.14 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts”.

Table 5.14. Degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	p=0.7877 (null hypothesis Hst not rejected)	p=0.1458 (null hypothesis Hks not rejected)	gamma=0.5606661 (standard error 0.1729323); null hypothesis Hgk rejected (p=0.001186469)	rho=0.6928744; null hypothesis Hsr rejected (p=4.585×10 ⁻⁹)	tau=0.5174761; null hypothesis Hkr rejected (p=1.78×10 ⁻⁷)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.14 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair

of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.6. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Based on Table 5.12 for each of five comparison tests Table 5.15 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts”.

Table 5.15. Degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of departures from a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	$p=0.8899$ (null hypothesis Hst not rejected)	$p=0.01904$ (null hypothesis Hks rejected)	$\gamma=0.5487013$ (standard error 0.1766411); null hypothesis Hgk rejected ($p=0.001894411$)	$\rho=0.6736606$; null hypothesis Hsr rejected ($p=1.737 \times 10^{-6}$)	$\tau=0.5017701$; null hypothesis Hkr rejected ($p=5.435 \times 10^{-7}$)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.15 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of departures from a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.4. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Based on Table 5.12 for each of five comparison tests Table 5.16 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts”.

Table 5.16. Degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
Distribution A	Distribution B	Sign test of paired samples	Bootstrap version of Kolmogorov-Smirnov two-sample test	Goodman-Kruskal gamma statistic	Spearman's rank correlation coefficient rho	Kendall's rank correlation coefficient tau
number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	$p=1$ (null hypothesis Hst not rejected)	$p=0.3233$ (null hypothesis Hks not rejected)	$\gamma=0.3266564$ (standard error 0.1945546); null hypothesis Hgk not rejected ($p=0.09315289$)	$\rho=0.4050271$; null hypothesis Hsr rejected ($p=0.002159$)	$\tau=0.3057519$; null hypothesis Hkr rejected ($p=0.001857$)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.16 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.6. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.17 shows some of the greatest ranking concepts from Table 5.12 in respect to start and end concepts in hyperlinks and departures and arrivals relating to them. Based on pair-wise comparison of columns 2 and 4 and columns 3 and 5 in Table 5.12 we wanted to identify every such concept that had a rich variety of departing and arriving hyperlinks which all still became traversed in exploration task, thus indicating a specifically favored concept. Therefore we defined a criterion to find concepts that had at least two departing and two arriving hyperlinks in “hyperlink network of 55 concepts” and all of their arriving and departing hyperlinks became traversed at least by

one student during exploration task. We managed to find six concepts meeting this criterion concerning favoured concept: Oxygen (6 departing and 9 arriving hyperlinks), Parent (6 departing and 4 arriving hyperlinks), Emotion (4 departing and 3 arriving hyperlinks), Happiness (2 departing and 4 arriving hyperlinks), Teacher (3 departing and 2 arriving hyperlinks) and Learning (2 departing and 2 arriving hyperlinks).

Table 5.17. Some of the greatest ranking concepts from Table 5.12 in respect to start and end concepts in hyperlinks and departures and arrivals relating to them.

In “hyperlink network of 55 concepts” (belonging to hyperlink network of the Wikipedia)		In exploration paths that students (n=49) traverse in “hyperlink network of 55 concepts” (belonging to hyperlink network of the Wikipedia)			
Some of the greatest ranking start concepts for hyperlinks (occurrences)	Some of the greatest ranking end concepts for hyperlinks (occurrences)	Some of the greatest ranking start concepts for traversed hyperlinks (occurrences)	Some of the greatest ranking end concepts for traversed hyperlinks (occurrences)	Some of the concepts having greatest number of departures (occurrences)	Some of the concepts having greatest number of arrivals (occurrences)
Human (16)	Human (11)	Human (14)	Human; Oxygen (9)	Human (80)	Happiness (55)
Education; Food (10)	Family (10)	Education; Plant (8)	Family (8)	Emotion (70)	Emotion; Love (48)
Plant; Water (8)	Biology; Oxygen (9)	Water (7)	Animal; Biology; Education; Love; Organism; Plant (6)	Happiness; Love (50)	Education (46)

Table 5.18 shows occurrences of *encountered and revisited concepts in exploration paths* among 55 concepts reachable in exploration from concept Human in “hyperlink network of 55 concepts”. For each student each concept is counted at most once. Concept Human was not counted when exploration started from it but if exploration later arrived to concept Human it was then counted. The numbers of encountered concepts can be contrasted with notion that statistically all 49 students together made $49 \times 20 = 980$ encounters with concepts which means that they should make on average $980/55 = 17.8$ encounters per each of 55 concepts belonging to “hyperlink network of 55 concepts”. Similarly for 18 male students should make on average 7.3 encounters per each of 55 concepts, and 31 female students on average 11.3 encounters per each of 55 concepts. Thus in Table 5.18 in six first columns can be seen that concepts that receive occurrences above just mentioned average values can be considered to have been specifically favored in exploration by all students, male students and female students, respectively.

Table 5.18 part 1 of 2 (starts here and continues on next page). Occurrences of encountered and revisited concepts in exploration paths (n=49) among 55 concepts reachable in exploration from concept Human in “hyperlink network of 55 concepts”.

Encountered concepts in exploration paths when each concept counted at most once for each student						Revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student					
All students (n=49)		Male students (n=18)		Female students (n=31)		All students (n=49)		Male students (n=18)		Female students (n=31)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Love	30	Human	12	Emotion	22	Emotion	23	Death	6	Emotion	17
Emotion	28	Diet_(nutrition)	9	Love	22	Love	17	Emotion	6	Love	13
Human	28	Animal	8	Adolescence	20	Education	16	Happiness	6	Education	11
Experience	26	Biology	8	Happiness	19	Happiness	15	Organism	6	Happiness	9
Happiness	26	Death	8	Experience	18	Death	12	Education	5	Biology	7
Adolescence	25	Disease	8	Family	17	Learning	10	Water	5	Learning	7
Biology	23	Experience	8	Education	16	Plant	10	Love	4	Death	6
Family	23	Love	8	Human	16	Biology	9	Oxygen	4	Family	6
Education	22	Organism	8	Biology	15	Organism	9	Plant	4	Plant	6
Death	21	Oxygen	8	Death	13	Water	9	Sun	4	Human	5
Organism	21	Plant	8	Organism	13	Human	8	Adolescence	3	Joy	5
Diet_(nutrition)	20	Happiness	7	Disease	12	Joy	8	Diet_(nutrition)	3	Leisure	5
Disease	20	Health	7	Friendship	12	Disease	7	Disease	3	Disease	4
Health	19	Joy	7	Health	12	Family	7	Human	3	Water	4
Joy	19	Nature	7	Joy	12	Oxygen	7	Joy	3	Adolescence	3
Animal	17	Sun	7	Mother	12	Adolescence	6	Learning	3	Health	3
Parent	17	Education	6	Child	11	Leisure	6	Biology	2	Nature	3
Plant	17	Emotion	6	Diet_(nutrition)	11	Sun	5	Animal	1	Organism	3
Child	16	Family	6	Learning	11	Health	4	Clothing	1	Oxygen	3
Friendship	16	Heart	6	Parent	11	Nature	4	Family	1	Teacher	2
Nature	16	Parent	6	Animal	9	Diet_(nutrition)	3	Father	1	Animal	1
Oxygen	16	Religion	6	Heart	9	Teacher	3	Health	1	Child	1
Heart	15	War	6	Nature	9	Animal	2	Leisure	1	Experience	1

Table 5.19 shows ranking of 55 concepts of “hyperlink network of 55 concepts” in respect to four characteristics: encountered concepts in exploration (based on Table 5.18), sum of departures and arrivals in exploration (based on Table 5.12), occurrences in word lists of students (based on Table 3.4) and sums of measures of importance given by each student (based on Table 3.4). To facilitate pair-wise comparison of rankings the ranking values are transformed to an equal ranking scale 1–55.

Table 5.18 part 2 of 2 (started on previous page and continues here).

Encountered concepts in exploration paths when each concept counted at most once for each student						Revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student					
All students (n=49)		Male students (n=18)		Female students (n=31)		All students (n=49)		Male students (n=18)		Female students (n=31)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Learning	15	Water	6	Plant	9	Father	2	Light	1	Father	1
Mother	15	Adolescence	5	Sibling	9	Mother	2	Mother	1	Mother	1
War	13	Child	5	Leisure	8	School	2	Nature	1	School	1
Sibling	12	Peace	5	Oxygen	8	War	2	School	1	Sun	1
Father	11	Father	4	Father	7	Child	1	Sibling	1	War	1
Sun	11	Friendship	4	War	7	Clothing	1	Teacher	1	Automobile	0
Water	11	Learning	4	School	6	Experience	1	War	1	Birth	0
Leisure	10	Teacher	4	Birth	5	Light	1	Automobile	0	Cat	0
Religion	10	Tree	4	Teacher	5	Sibling	1	Birth	0	Clothing	0
School	9	Light	3	Water	5	Automobile	0	Cat	0	Computer	0
Teacher	9	Mother	3	Old_age	4	Birth	0	Child	0	Diet_(nutrition)	0
Peace	8	School	3	Religion	4	Cat	0	Computer	0	Dog	0
Sea	7	Sea	3	Sea	4	Computer	0	Dog	0	Food	0
Television	7	Sibling	3	Sun	4	Dog	0	Experience	0	Friendship	0
Tree	7	Television	3	Television	4	Food	0	Food	0	God	0
Light	6	Automobile	2	Work	4	Friendship	0	Friendship	0	Heart	0
Birth	5	Clothing	2	God	3	God	0	God	0	Home	0
God	5	God	2	Light	3	Heart	0	Heart	0	House	0
Old_age	5	Leisure	2	Peace	3	Home	0	Home	0	Light	0
Work	5	Travel	2	Tree	3	House	0	House	0	Music	0
Clothing	3	Home	1	Clothing	1	Music	0	Music	0	Old_age	0
Travel	3	House	1	Food	1	Old_age	0	Old_age	0	Parent	0
Automobile	2	Music	1	Home	1	Parent	0	Parent	0	Peace	0
Home	2	Old_age	1	House	1	Peace	0	Peace	0	Pet	0
House	2	Work	1	Travel	1	Pet	0	Pet	0	Religion	0
Food	1	Birth	0	Automobile	0	Religion	0	Religion	0	Sea	0
Music	1	Cat	0	Cat	0	Sea	0	Sea	0	Sibling	0
Cat	0	Computer	0	Computer	0	Telephone	0	Telephone	0	Telephone	0
Computer	0	Dog	0	Dog	0	Television	0	Television	0	Television	0
Dog	0	Food	0	Music	0	Travel	0	Travel	0	Travel	0
Pet	0	Pet	0	Pet	0	Tree	0	Tree	0	Tree	0
Telephone	0	Telephone	0	Telephone	0	Work	0	Work	0	Work	0

Based on Table 5.19 for each of three comparison tests Table 5.20 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between four rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration, sum of departures and arrivals in exploration, occurrences in word lists of students and sums of measures of importance given by each student.

Table 5.19 part 1 of 2 (starts here and continues on next page). Ranking of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration, sum of departures and arrivals in exploration, occurrences in word lists of students and sums of measures of importance given by each student, transformed to equal ranking scale 1–55. A special case for ranking comparison are concepts that did not become encountered in exploration (Cat, Dog, Computer, Pet and Telephone), indicated with an asterisk (*).

55 concepts (common nouns) in conceptual structures	Ranking values transformed to equal scale 1–55 (how many positions higher than ranking of encountered concepts in exploration)			
Concept as a Wikipedia article title (<i>corresponding concept as generated by students if not the same concept</i>)	Encountered concepts in exploration (all 49 explorations) (n=49)	Sum of departures and arrivals in exploration (all 49 explorations) (n=49)	Occurrences in word lists of students (n=103)	Sums of measures of importance given by each student (n=103)
Love	1	4 (-3)	5.5s (-4.5s)	3 (-2)
Emotion	2.5s	1 (+1.5s)	40s (-37.5s)	30 (-27.5s)
Human	2.5s	2 (+0.5s)	10 (-7.5s)	9 (-6.5s)
Experience	4.5s	27 (-22.5s)	40s (-35.5s)	40 (-35.5s)
Happiness	4.5s	3 (+1.5s)	24s (-19.5s)	18 (-13.5s)
Adolescence (<i>young_ (person)</i>)	6	9 (-3)	45s (-39s)	53 (-47)
Biology	7.5s	8 (-0.5s)	45s (-37.5s)	49 (-41.5s)
Family	7.5s	6 (+1.5s)	1 (+6.5s)	1 (+6.5s)
Education	9	5 (+4)	19.5s (-10.5s)	19 (-10)
Death	10.5s	7 (+3.5s)	4 (+6.5s)	7 (+3.5s)
Organism	10.5s	10.5s (0s)	51.5s (-41s)	50 (-39.5s)
Diet_(nutrition) (<i>nutriment</i>)	12.5s	15.5s (-3s)	51.5s (-39s)	43 (-30.5s)
Disease	12.5s	14 (-1.5s)	40s (-27.5s)	54 (-41.5s)
Health	14.5s	15.5s (-1s)	19.5s (-5s)	14 (+0.5s)
Joy	14.5s	12 (+2.5s)	15s (-0.5s)	17 (-2.5s)
Animal	17s	20 (-3s)	9 (+8s)	12 (+5s)
Parent	17s	22s (-5s)	51.5s (-34.5s)	36 (-19s)
Plant	17s	10.5s (+6.5s)	22 (-5s)	21 (-4s)
Child	20.5s	22s (-1.5s)	15s (+5.5s)	16 (+4.5s)
Friendship (<i>friend</i>)	20.5s	25.5s (-5s)	2 (+18.5s)	2 (+18.5s)
Nature	20.5s	19 (+1.5s)	12 (+8.5s)	11 (+9.5s)
Oxygen	20.5s	13 (+7.5s)	51.5s (-31s)	35 (-14.5s)
Heart	24s	35 (-11s)	40s (-16s)	33.5s (-9.5s)
Learning	24s	18 (+6s)	28s (-4s)	25 (-1s)
Mother	24s	22s (+2s)	28s (-4s)	22 (+2s)
War	26	25.5s (+0.5s)	45s (-19s)	55 (-29)
Sibling (<i>sister</i>)	27	29s (-2s)	51.5s (-24.5s)	52 (-25)
Father	29s	29s (0s)	34.5s (-5.5s)	24 (+5s)
Sun	29s	24 (+5s)	15s (+14s)	15 (+14s)
Water	29s	17 (+12s)	7.5s (+21.5s)	5 (+24s)
Leisure (<i>freetime</i>)	31.5s	29s (+2.5s)	34.5s (-3s)	28.5s (+3s)
Religion	31.5s	33 (-1.5s)	30.5s (+1s)	42 (-10.5s)
School	33.5s	31.5s (+2s)	5.5s (+28s)	8 (+25.5s)
Teacher	33.5s	31.5s (+2s)	51.5s (-18s)	51 (-17.5s)
Peace	35	34 (+1)	45s (-10s)	37 (-2)

Table 5.19 part 2 of 2 (started on previous page and continues here).

55 concepts (common nouns) in conceptual structures	Ranking values transformed to equal scale 1–55 (how many positions higher than ranking of encountered concepts in exploration)			
Concept as a Wikipedia article title (<i>corresponding concept as generated by students if not the same concept</i>)	Encountered concepts in exploration (all 49 explorations) (n=49)	Sum of departures and arrivals in exploration (all 49 explorations) (n=49)	Occurrences in word lists of students (n=103)	Sums of measures of importance given by each student (n=103)
Sea	37s	36.5s (+0.5s)	40s (-3s)	47 (-10s)
Television	37s	42 (-5s)	28s (+9s)	32 (+5s)
Tree	37s	36.5s (+0.5s)	24s (+13s)	31 (+6s)
Light	39	38 (+1)	34.5s (+4.5s)	38.5s (+0.5s)
Birth	41s	39.5s (+1.5s)	11 (+30s)	10 (+31s)
God	41s	39.5s (+1.5s)	45s (-4s)	45.5s (-4.5s)
Old_age (<i>elderness</i>)	41s	41 (0s)	34.5s (+6.5s)	44 (-3s)
Work	41s	44 (-3s)	3 (+38s)	4 (+37s)
Clothing (<i>cloth</i>)	44.5s	43 (+1.5s)	34.5s (+10s)	27 (+17.5s)
Travel	44.5s	48 (-3.5s)	51.5s (-7s)	38.5s (+6s)
Automobile (<i>car</i>)	47s	46s (+1s)	24s (+23s)	33.5s (+13.5s)
Home	47s	46s (+1s)	13 (+34s)	13 (+34s)
House	47s	46s (+1s)	17.5s (+29.5s)	20 (+27s)
Food	49.5s	49 (+0.5s)	7.5s (+42s)	6 (+43.5s)
Music	49.5s	50 (-0.5s)	30.5s (+19s)	28.5s (+21s)
Cat*	53s	53s (0s*)	26 (+27s*)	45.5s (+7.5s*)
Computer*	53s	53s (0s*)	21 (+32s*)	26 (+27s*)
Dog*	53s	53s (0s*)	17.5s (+35.5s*)	23 (+30s*)
Pet*	53s	53s (0s*)	34.5s (+18.5s*)	41 (+12s*)
Telephone* (<i>phone</i>)	53s	53s (0s*)	51.5s (+1.5s*)	48 (+5s*)

Relying on Table 5.19, three tables, Table 5.21, Table 5.22 and Table 5.23, enable to contrast ranking based on encountered concepts in exploration with three rankings: ranking based on sum of departures and arrivals in exploration, ranking based on occurrences in word lists of students and ranking based on sums of measures of importance given by each student. These three tables show for each pair of rankings some of the greatest and smallest ranking differences for concepts among observed 55 concepts. It seems that concepts having higher ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration include for example natural substances (Water and Oxygen) whereas for example emotional issues have higher ranking for encountered concepts in exploration than for sum of departures and arrivals in exploration.

Table 5.20. Degrees of dependency between four rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration (n=49), sum of departures and arrivals in exploration (n=49), occurrences in word lists of students (n=103) and sums of measures of importance given by each student (n=103).

Compared pair of distributions		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman’s rank correlation coefficient rho</i>	<i>Kendall’s rank correlation coefficient tau</i>
encountered concepts in exploration (n=49)	sum of departures and arrivals in exploration (n=49)	gamma=0.8838348 (standard error 0.09177504); null hypothesis Hgk rejected (p=0)	rho=0.9583967; null hypothesis Hsr rejected (p<2.2x10 ⁻¹⁶)	tau=0.8716607; null hypothesis Hkr rejected (p<2.2x10 ⁻¹⁶)
encountered concepts in exploration (n=49)	occurrences in word lists of students (n=103)	gamma=0.01615272 (standard error 0.200926); null hypothesis Hgk not rejected (p=0.935926)	rho=0.02128859; null hypothesis Hsr not rejected (p=0.8774)	tau=0.01546115; null hypothesis Hkr not rejected (p=0.8724)
encountered concepts in exploration (n=49)	sums of measures of importance given by each student (n=103)	gamma=0.09065551 (standard error 0.195036); null hypothesis Hgk not rejected (p=0.6420645)	rho=0.1246614; null hypothesis Hsr not rejected (p=0.3645)	tau=0.08908127; null hypothesis Hkr not rejected (p=0.3445)
sum of departures and arrivals in exploration (n=49)	occurrences in word lists of students (n=103)	gamma=0.04046243 (standard error 0.1991854); null hypothesis Hgk not rejected (p=0.839026)	rho=0.08030663; null hypothesis Hsr not rejected (p=0.56)	tau=0.03905802; null hypothesis Hkr not rejected (p=0.683)
sum of departures and arrivals in exploration (n=49)	sums of measures of importance given by each student (n=103)	gamma=0.1208791 (standard error 0.192932); null hypothesis Hgk not rejected (p=0.5309626)	rho=0.1882198; null hypothesis Hsr not rejected (p=0.1688)	tau=0.1196902; null hypothesis Hkr not rejected (p=0.2009)
occurrences in word lists of students (n=103)	sums of measures of importance given by each student (n=103)	gamma=0.7863248 (standard error 0.1222799); null hypothesis Hgk rejected (p=1.271583x10 ⁻¹⁰)	rho=0.9042751; null hypothesis Hsr rejected (p<2.2x10 ⁻¹⁶)	tau=0.7645224; null hypothesis Hkr rejected (p=8.882x10 ⁻¹⁶)

Table 5.21. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus sum of departures and arrivals in exploration (n=49). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on sum of departures and arrivals in exploration and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Water	+12s	Experience	-22.5s	Cat*; Computer*; Dog*; Father; Old_age; Organism; Pet*; Telephone*	0s
Oxygen	+7.5s	Heart	-11s	Food; Human; Sea; Tree; War	+0.5s
Plant	+6.5s	Friendship; Parent; Television	-5s	Biology; Music	-0.5s
Learning	+6s	Travel	-3.5s	Light; Peace	+1
Sun	+5s	Adolescence; Love	-3	Automobile; Home; House	+1s
Education	+4	Animal; Diet_(nutrition); Work	-3s	Health	-1s
		Sibling	-2s		

Table 5.22. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus occurrences in word lists of students (n=103). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for occurrences in word lists of students than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for occurrences in word lists of students than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on occurrences in word lists of students and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Food	+42s	Organism	-41s	Joy	-0.5s
Work	+38s	Adolescence; Diet_(nutrition)	-39s	Religion	+1s
Dog*	+35.5s	Biology; Emotion	-37.5s	Telephone*	+1.5s
Home	+34s	Experience	-35.5s	Leisure; Sea	-3s
Computer*	+32s	Parent	-34.5s	God; Learning; Mother	-4s
Birth	+30s	Oxygen	-31s		

Table 5.23. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus measures of importance given by each student (n=103). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for sums of measures of importance given by each student than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for sums of measures of importance given by each student than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on sums of measures of importance given by each student and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Food	+43.5s	Adolescence	-47	Health; Light	+0.5s
Work	+37s	Biology; Disease	-41.5s	Learning	-1s
Home	+34s	Organism	-39.5s	Mother	+2s
Birth	+31s	Experience	-35.5s	Love; Peace	-2
Dog*	+30s	Diet_(nutrition)	-30.5s	Joy	-2.5s
Computer*; House	+27s	War	-29		

It also seems that concepts having higher ranking position for occurrences in word lists of students or for sums of measures of importance given by each student than for encountered concepts in exploration include for example Food, Work and Home, whereas for example Adolescence and Organism have higher ranking for encountered concepts in exploration than for occurrences in word lists of students or for sums of measures of importance given by each student.

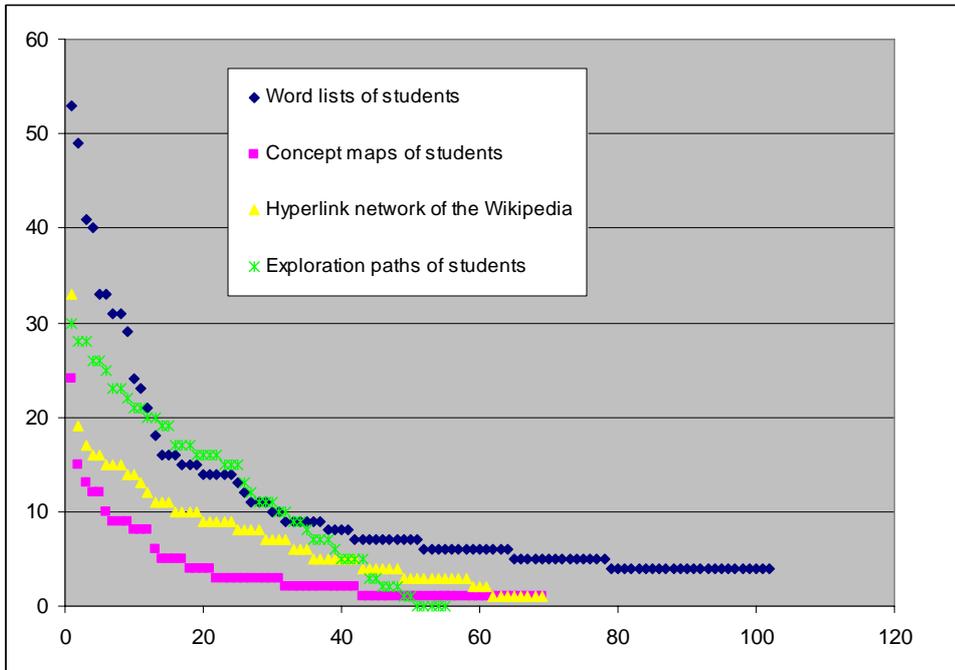


Figure 5.8. Occurrences of concepts a) among 102 core concepts in word lists generated by students mentioned by at least four students ($n=103$) (based on Table 3.4), b) in relationships in concept maps drawn by students ($n=103$) between 69 shared concepts (based on Table 5.5), c) in hyperlink network of Wikipedia between 69 shared concepts (based on Table 5.5), and d) in traversed links in exploration paths of students in “hyperlink network of 55 concepts” when each concept counted at most once for each student ($n=49$) (based on Table 5.18). Each of these four occurrence values on y axis are shown separately in descending order so that while steps on x axis go through concepts one by one these concepts are not processed in same order along x axis for these four parameters and they have only partial overlap due to different vocabulary sizes.

5.5. Findings and their relation to the entity of the dissertation

We think that the proposed method can facilitate pedagogically motivated knowledge management in many ways. The method relies on a constantly growing and collaboratively fine-tuning large online knowledge resource, the Wikipedia. The method supports a learner to explore independently the densely cross-linked pieces of up-to-date knowledge following spontaneously her own educational needs. By extracting conceptual relationships from hyperlinks of the Wikipedia articles the method illustrates intuitively learning paths that can be considered to be the most promising ways to relate concepts in respect to being relying on recommendations given by a diverse community of Wikipedia editors. The learner can build and experiment with compact visualizations that represent her understanding and taken perspectives. Resulting concept maps indicate clearly the relations of facts supporting constructive learning paradigms and creating sustainable customized learning objects. The learning process is inherently self-regulating since previous learning paths and the most probable future directions are efficiently presented and comparable all the time. Evaluating various perspectives with a critical attitude is well supported.

Publication [P2] describes a method that can be used as a standalone application or included into various different types of educational software. The method can be added

as an augmentation to for example educational framework we described in publication [P1]. Based on promising results in initial experiments, after publication of the publication [P2] we have carried out wider empirical user testing in collaborative environment which seems to have provided increased possibilities for understanding properties of the proposed method. Besides text, the concept maps could be easily transformed to exploit multimedia content. In addition, various metrics could be applied to assist the learner to identify the most mature and trusted content in the online knowledge resource. Thus the method could promote using the most extensive and reliable learning paths.

Proceeding in the learning content space can be performed with manageable steps in abstraction level and minimizing excessive cognitive load. All concept maps built by an individual learner can be agglomerated to greater entities and used as customized learning objects. The method is flexible since it can be applied equally well to exploring details of a specific domain or to ideation of distant associations. The method addresses typical requirements for creative problem solving providing surprising viewpoints yet enabling sustainable continuity to old knowledge. Indeed the functioning of the method described in [P2] gets extended value by various approach that are introduced in publications [P3] and [P4]. [P3] introduces using statistics about Wikipedia articles to offer additional analysis to assist meaningful browsing in knowledge structures and [P4] introduces possibility to exploit educationally observation of parallel learning paths and temporal versions of knowledge structures. Publication [P5] introduces wiki architecture to manage collections of educational knowledge with collectively produced concept maps and we think that of method described in [P1] can be used as an aid to create and edit pedagogically meaningfully individual concept maps. Also the method for finding the shortest paths between the learner's knowledge and the learning objective as introduced in publication [P6] can be seen as an expansion and corresponding idea to the method introduced in publication [P1].

PART III. Generation of alternative personalized learning paths in link based knowledge structures by using statistical and historical data

Chapter 6. Generating personalized learning paths from the Wikipedia by using article statistics

In publication [P3] we propose a new semi-automated method for generation of *personalized learning paths* by following hyperlink chains between articles of the Wikipedia online encyclopedia based on various *statistics of the articles*. The learning paths are represented with gradually built concept maps based on the hyperlink network of the Wikipedia online encyclopedia. On a more general level besides the Wikipedia, we propose methodology that supports exploiting knowledge structures in collaboratively maintained knowledge repositories in the form of wikis.

We now here first explain the basic idea and motivation about using statistical features of the Wikipedia articles to generate alternative learning paths and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational tasks. More details can be read from the original publication [P3]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P3]. Figure 6.1 illustrates the main idea of the method proposed in publication [P3].

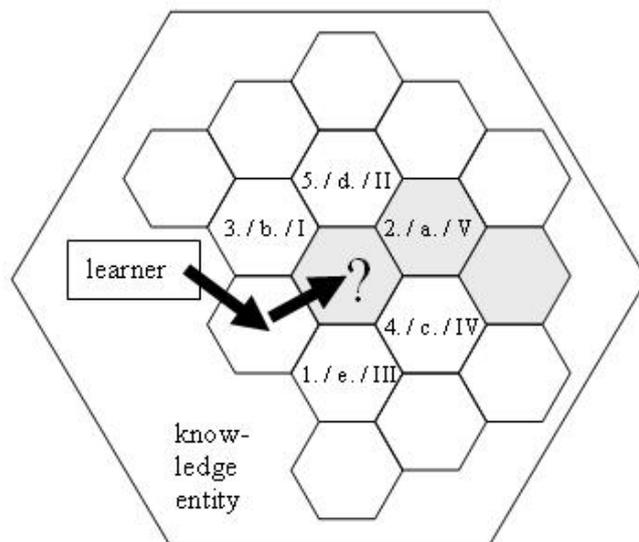


Figure 6.1. Main idea of the method proposed in publication [P3] for generating personalized learning paths by exploring in the hyperlink network of the Wikipedia based on ranking of article statistics.

Similarly as in Figure 5.1, also in Figure 6.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. We are extending the proposal of publication [P2] by enabling use of alternative strategies for a single learner traversing hyperlinks between articles. Now we use statistics about the Wikipedia articles to generate rankings for hyperlinks of an article in respect to alternative perspectives represented by target articles accessibly through these hyperlinks. In Figure 6.1 the alternative rankings in descending order of priority are represented by three parallel orderings based on Arabic numbers (1., 2., 3.,...), Latin alphabets (a., b., c.,...) and Roman numbers (I, II, III,...).

The learner's exploration path in the hyperlink network so far is shown by a chain of arrows. Surrounding the current article (a hexagon with a question mark) are articles reachable through hyperlinks of current article, each one of them supplied with three alternative ranking values in respect to three different statistical features of articles. When selecting what hyperlink to traverse next in further exploration, if the learner decides to prioritize ranking values shown in Latin alphabets, the highest-ranking hyperlink would lead her to article supplied with notation "2./a./V". In this example, grayed hexagons indicate a possible chain of hyperlinks that the learner is expected to traverse from current article.

6.1. Ontology construction and accumulating knowledge

Pirrone et al. (Pirrone et al. 2005) proposed automated learning path generation inside a domain ontology relying on a weighted graph and A* (i.e. A star) search algorithm. In publication [P3] We suggested extending the use of ontologies extracted from the Wikipedia to be applied in building personalized learning paths. With an aim to enhance the quality of articles, the Wikipedia community has been labelling in a specific review process some satisfactory articles as "good articles" and even more professional ones as "featured articles". Blumenstock (Blumenstock 2008) showed that the featured articles can be recognized correctly with the accuracy of 96 percent using a simple heuristic that classifies articles with more than 2000 words as "featured" and articles with fewer than 2000 words as "random". Thomas and Sheth (Thomas & Sheth 2007) showed that when comparing labelled good articles to other non-stub articles having at least 50 revision milestones they found no statistically significant difference in convergence to a semantically stable state. These two previous results indicate that the maturity of an article can be measured relatively well even with simple parameters and motivated us to attempt to identify few *basic features of a Wikipedia article* that can be easily measured to create rankings for hyperlinks, highlighting alternative pedagogical perspectives that they provide for the learner's exploration in the hyperlink network.

When generating automatically favourable learning paths the learner should have a suitable balance between constraints for sustainability and freedom of association. Nastase and Szpakowicz (Nastase & Szpakowicz 2006) introduced an incremental learning algorithm that mimics how a human reader accumulates knowledge and exploits it to process new text. For natural language processing applications, various

confidence measures have been developed to estimate the probability of correctness of the outputs (Gandrabor et al. 2006). Pavlovic (Pavlovic 2008) proposed detecting semantic structures in a network based on available static data and ranking of paths. We think that our proposed method is dealing with a same kind of goal and that the statistics concerning articles can be useful criteria for ranking the paths. Haruechaiyasak and Damrongrat (Haruechaiyasak & Damrongrat 2008) proposed recommending related articles for the educationally tailored Wikipedia Selection for Schools based on similarity measures computed for topic distribution profiles of the articles.

There are some challenges with the learner's exploration in hyperlink network. The more hyperlinks are available at current article, the more *alternative learning paths* can be provided to the learner although making it also harder to choose one of them through comparison. Using many parallel measures for ranking hyperlinks can enhance possibility to systematically differentiate alternative rankings but unfortunately also increases computational complexity. We wanted to minimize the computational cost of searches in the hyperlink network and decided to evaluate only those articles that can be reached within a distance of one hyperlink step from the article where the learner's exploration currently stays. Thus our method can be used even with modest technological resources in accordance with promoting design principle of access for all. We think that there is a whole new research domain opening in this ranking-based exploration of wiki environments.

6.2. Ranking hyperlinks based on article statistics

We propose that many statistical features about the hyperlink's target article can be retrieved as useful indicators about the augmenting perspectives that the target article represents in relation to the current article. This enables getting target articles of hyperlinks to be promoted in varying order of preference, depending on to which statistical features have been given priority in ranking. In publication [P3] we concluded based on our analysis to name five key functions of the Wikipedia and corresponding measurable features for ranking of hyperlinks. They are: adding new content (*article size*), editing content (*editing rate*), providing cross-linking (*hierarchy of hyperlinks*), explaining concepts and their relation (*repetition of hyperlink terms*) and using articles as a reference (*viewing rate*). Each of these five features enable relatively straightforward ranking of hyperlinks of any Wikipedia article. We do not expect these five key functions necessarily to cover most fundamental ontological features of the Wikipedia but anyway to define a new useful approach to classify ranking alternatives in exploration of hyperlink network.

We think that the order of appearance of hyperlinks in the article is the simplest ranking of hyperlinks to exploit since it is inherently available in the article text. Statistical features of an article can be computed directly from the article or its *revision history*, or then retrieved from the open *statistics database* provided by the Wikipedia Foundation. Several specialized web sites provide an easy interface for making queries from the statistics database. In preliminary testing we evaluated a varied randomized

sample of 100 Wikipedia articles. Based on randomized sample of 100 Wikipedia articles we identified what kinds of target articles of hyperlinks appear to become logically or misleadingly favoured when ranking is performed in respect to each of five features (see Table 6.1 (originally published as Table 1 in publication [P3])).

Table 6.1. (originally published as Table 1 in publication [P3]). Some favourably and misleadingly promoted types of Wikipedia articles when their corresponding hyperlinks are ranked in respect to five measurable features.

	Hierarchy of hyperlinks	Repetition of hyperlink terms	Article size	Viewing rate	Editing rate
<i>Favourably promoted</i>	- compact definitions in the beginning - later illustrative and more detailed uses, alternatives	- everyday vocabulary - general topic with many variations and sub-branches	- key terms of each field - stabilized knowledge, biographies	- recent news topics, trends in popular culture - technology, entertainment, celebrities	- controversial, non-stabilized or actively evolving - science, politics
<i>Misleadingly promoted</i>	- any complex term that needs explanation - unnecessarily broad or general terms	- use of synonyms or it/this hides the terms - long terms less likely to be repeated	- single author's devotion without general interest - article not condensed or yet split	- tourist information - checks for equations, minor facts or spelling	- target of vandalism or consistent rewriting - translated article suffering from low rate

The learner's exploration in hyperlink network should fruitfully support principles of constructivism and transferable learning. Each selected hyperlink progressively expands a concept map that is shown to the learner, defining learning paths highlighting perspectives that depend on ranking alternative the learner has decided to prioritize. At each step, according to her personal needs, the learner can choose which type of ranking is used for sorting the hyperlinks. The hyperlinks are sorted based on five different rankings that are generated from the statistics of the hyperlinked articles in accordance with five key functions of the Wikipedia and respective measurable features as discussed above. In experiments described in publication [P3] we used following definitions for each of five key functions and in later supplementing experiments we have analyzed some additional measurable features as we will discuss a bit later in this Chapter 6.

“*Hierarchy of hyperlinks*” denotes showing hyperlinks in the natural order of increasing distance from the beginning of the article. This ordering is motivated by that a Wikipedia article often starts with a compact definition containing a few hyperlinks. Respectively, the hyperlinks in the end of current article likely point to articles whose titles emphasize giving broader details of the current article. “*Repetition of hyperlink terms*” denotes showing hyperlinks in a descending order of significance based on how many times the word (or group of words) forming the title of hyperlink's target article is mentioned in the current article, anywhere in its full textual content. This ordering is motivated by an assumption that the title of target article for each hyperlink defines a key term for current article. The more this key term is repeated in the text of current article, the more it seems to indicate that the corresponding target article is highly involved in formulating relations with the current article.

“*Article size*” denotes showing hyperlinks in a descending order based on the total amount of characters in the target article text. A motivation for this ordering is that a

bigger article size obviously indicates more detailed content than a smaller article size. The value of article size is approximated with the file size in bytes that is extracted from the header of the target article file. “*Viewing rate*” denotes showing hyperlinks in a descending order based on frequency of visits to view the hyperlink’s target article by the global community. This ordering is motivated by the assumption that an article with a high viewing rate has a higher general interest than an article with a low viewing rate. This value represents total number of views per previous full month. This information is retrieved from online service (Wikipedia article traffic statistics 2009) that relies on data gathered from Wikipedia’s squidbased cache server cluster.

“*Editing rate*” denotes showing hyperlinks in a descending order based on frequency of editing the hyperlink’s target article by the global community. A motivation for this ordering is that higher editing rates seem to indicate more verified content than lower editing rates. In publication [P3] the value of editing rate is approximated with the total number of edits for current article since its creation. However, in supplementing experiments which will be discussed later in this Chapter 6 we have carried out ranking of hyperlinks also based such definition of edit rate that is number of edits during a timespan divided by article size and we consider that this later definition usefully makes gained rate value more proportional than earlier definition. This information is retrieved from online service (Wikipedia page history statistics 2009) that builds an edit history overview page for the article with the given name. Besides these five principal features, we still suggest a supplementing feature that is a user-defined weighted mixture of them all.

There have been proposals to visually highlight the most mutually agreed segments in a Wikipedia article based on simple quality measures. High survival time of a single edit does not guarantee reliably its trustworthiness (Luyt et al. 2008). Adler and de Alfaro (Adler & de Alfaro 2007) proposed a measure relying on author’s reputation that can be gained if the edits he/she performs are preserved by subsequent authors. It seems challenging to develop measures taking simultaneously into account the semantics of the article network and collective contribution patterns coming from authors and readers. Our method tries to address these issues.

6.3. Building learning paths in hyperlink network of the Wikipedia

Empirical testing of the proposed method was carried out with a sample of 30 most frequent nouns in English retrieved from British National Corpus (Kilgarriff 2009). To illustrate the rich varied perspectives gained with our method Table 6.2 (originally published as Table 2 in publication [P3]) shows target articles of eight highest-ranking hyperlinks of Wikipedia article “Life” (as of October 2009). In each major column of the table hyperlinks are ranked separately based on each of the five measurable features discussed above. The columns “Main text” and “Only intro” indicate if the ranking is done for all hyperlinks of the full article text (i.e. full text section) or only for hyperlinks mentioned in the introduction section before the table of contents (i.e. intro text

section). Applying ranking only to those hyperlinks that are mentioned in introduction section seems to help highlighting fundamental relations and improves computational performance thus decreasing delay of getting results with the method.

Table 6.2. (originally published as Table 2 in publication [P3]). Ranking of hyperlinks of article "Life" in respect to five features.

Rank	Hierarchy of hyperlinks (ordinal number)		Repetition of hyperlink terms (times)		Article size (bytes)		Viewing rate (times per month)		Editing rate (total number of edits)	
	Main text	Only intro	Main text	Only intro	Main text	Only intro	Main text	Only intro	Main text	Only intro
1	Biota (ecology) 1	Biota (ecology) 1	Organism 59	Organism 59	Evolution 525544	Fungus 488952	Earth 372525	Earth 372525	Evolution 12233	Earth 9152
2	Object (philosophy) 2	Object (philosophy) 2	RNA 41	Gene 38	Fungi 489093	Metabolism 456427	Water 286508	Water 286508	Earth 9152	Philosophy 6905
3	Biological process 3	Biological process 3	Gene 38	Earth 33	Fungus 488952	Earth 417499	Evolution 206918	Religion 192527	Aristotle 7089	Death 6467
4	Death 4	Death 4	Earth 33	Biology 26	Metabolism 456427	Bacteria 407412	Religion 192527	Philosophy 180609	Philosophy 6905	Religion 5850
5	Biology 5	Biology 5	Evolution 32	Animal 25	Bird 440284	Archaea 354696	Aristotle 190096	Animal 173059	Death 6467	Water 5828
6	Organism 6	Organism 6	Biology 26	Plant 21	Earth 417499	Philosophy 220220	Virus 189972	Bacteria 153442	Religion 5850	Biology 5340

We can sum all types of rankings together for each hyperlink. Then three highest-ranking hyperlinks in descending order for the main text are Evolution, Earth and Organism, and for only the introduction section Earth, Philosophy and Organism. When ranking is done only for the hyperlinks mentioned in the introduction section (i.e. intro text section), the promoted hyperlinks appear to be more shared among various perspectives than when ranking is done for all hyperlinks of the full article text (i.e. full text section), and it can originate from a practice that introduction section of an article typically may offer a relatively diverse compact set of hyperlinks while the text of introduction section aims to position the article in broader context of other articles. When we evaluated characteristics emerging with each feature in Table 6.2 our findings matched well with our previously made hypothesis about distinctive characteristics for each feature used in ranking of hyperlinks (see Table 6.1).

We produced a set of *learning paths* in the form of concept maps by exploring hyperlink chains following the ranking in respect to five features described in Subchapter 6.2. We continued testing with the previous sample of 30 English nouns. Figure 6.2 (originally published as Figure 1 in publication [P3]) shows concept maps that we produced for each of five perspectives when taking into account all hyperlinks in the full article text (i.e. full text section). Relation statements were extracted from sentences surrounding the hyperlinks with a method introduced in our previous work (publication [P2]). The method enables the learner to build concept maps with a free design in respect to branching, crosslinking and loops.

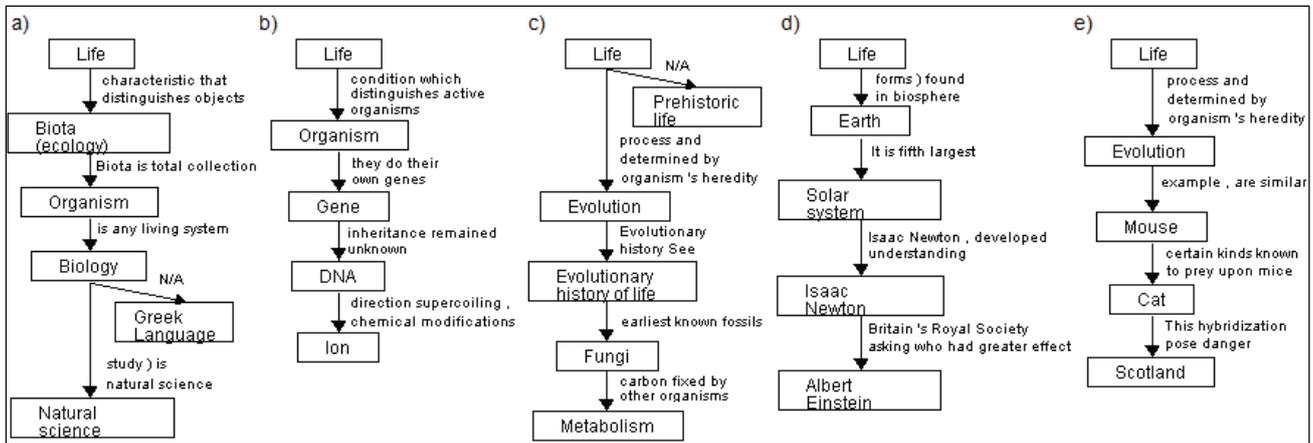


Figure 6.2. (originally published as Figure 1 in publication [P3]). Learning paths starting from article "Life" with five alternative perspectives: a) hierarchy of hyperlinks, b) repetition of hyperlink terms, c) article size, d) viewing rate, and e) editing rate.

Evaluating the learning paths introduced by each of the five features gave promising results. The learning paths seemed to offer some distinctive perspectives corresponding to our previous hypothesis that we outlined in Table 6.1. Hierarchy of hyperlinks (Figure 6.2a) produced a learning path that remains constantly on relatively high level of conceptual hierarchy in the topic. This type of learning paths could effectively introduce for example main chapters of the curriculum. Repetition of hyperlink terms (Figure 6.2b) produced a path that goes through conceptual structures of the topic across various hierarchical levels. This type of path could suit well to learning how the curriculum in deeper levels relies on rich variations of some basic conceptual components. Article size (Figure 6.2c) produced a path highlighting a collection of the most broadly documented concepts of the topic. This type of path could help in getting idea about the most respected and stabilized parts of the curriculum. Viewing rate (Figure 6.2d) produced a path showing those concepts of the topic that get the most attention from the general public. This type of path could indicate which parts of the curriculum are the most referenced ones. Editing rate (Figure 6.2e) produced a path that offers concepts in the topic that are actively debated by the general public. This type of path could illustrate the parts of curriculum that are involved in constructive criticism and reconsideration.

While ranking the hyperlinks, major articles can easily dominate all rankings and we suggest to create more distinctive diversity to different rankings by normalizing comparable statistics of articles somehow. We identified that a promising way to identify *proportional values* instead of absolute values can be based on idea of information density, i.e. statistical value per one unit of information. Thus, in practice for example hierarchy of hyperlinks, repetition of hyperlink terms, viewing rate and editing rate could be considered proportionally, for example in relation to article size.

Table 6.3 shows for 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks for departing and arriving hyperlinks (full listing is shown in Appendix U). Table 6.4 shows the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms for departing and arriving hyperlinks (full listing is shown in Appendix V).

We decided to make some further analysis about the behavior of statistical features of Wikipedia articles and its effect on chaining concepts in a way that could be pedagogically beneficial, and we identified that indeed especially the feature we have earlier referred to as “editing rate” seems to have correlations with “article size”. To suggest a compact and simple yet expressive collection of statistical features that offer alternative emphasis we thus decided to replace in our further analysis the feature “editing rate” with a feature “*edit rate per article size*” which seemed to offer promising results.

There can be many fruitful alternative ways to define statistical features by using varying time ranges. Table 6.5 enables to compare for Wikipedia articles corresponding to 102 core concepts following statistical features that offer one possible approach relying on one selected time range: article size (file size in bytes) in end of February 2008, viewing rate in February 2008 (number of views during February 2008), editing rate (number of edits during year 2007) and editing rate per article size (number of edits during year 2007 divided by article size in end of February 2008). When considering 55 concepts belonging to “hyperlink network of 55 concepts” it can be seen from Table 6.5 that three highest-ranking concepts for each four rankings based statistical features show varying topical emphasis and are in decreasing order of ranking: Cat, Oxygen and Sun (ranking based on article size); Love, Dog and Cat (ranking based on viewing rate); Television, Cat and War (ranking based on editing rate); and Mother, Home and Child (ranking based on editing rate per article size).

Based on Table 6.5 for each of five comparison tests Table 6.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between four rankings of 102 core concepts in respect to following statistical features of Wikipedia articles: article size (file size), views, edits and edits per article size.

Table 6.3 part 1 of 2 (starts here and continues on next page). For 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks for departing and arriving hyperlinks (full listing shown in Appendix U). If observed concept has only one departing/arriving hyperlink then observed concept is supplied with an asterisk (*). Value of “position among hyperlinks departing from Wikipedia article of start concept” indicates for the highest-ranking start concept or end concept what is its ranking position among all start concepts (in natural order of increasing distance from the beginning of the article) of those hyperlinks that arrive to current end concept (N/A = not available).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (position among hyperlinks departing from Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (position among hyperlinks departing from Wikipedia article of start concept)
Adolescence	Childhood (1)		Adolescence	Childhood (1)
Animal	Organism (1)		Animal	Plant (2)
Atmosphere_of_Earth	Oxygen (1)		Atmosphere_of_Earth	Nature (5)
* Automobile	Oxygen (1)		Automobile	Oxygen (1)
Bed	Infant (1)		* Bed	Dream (3)
Biology	Evolution (1)		Biology	Evolution (1)
Birth	Animal (1)		* Birth	Parent (N/A)
Book	Paper (1)		Book	Paper (1)
Bread	Water (1)		* Bread	Food (4)
Cat	Human (1)		Cat	Dog (2)
Child	Parent (1)		Child	Parent (1)
Childhood	Child (1)		Childhood	Child (1)
City	Automobile (1)		* City	Human (N/A)
Clock	Time (1)		Clock	Time (1)
Clothing	Religion (1)		Clothing	Paper (4)
Computer	Television (1)		Computer	Clock (N/A); Food (N/A)
Death	Organism (1)		Death	Disease (2)
Diet_(nutrition)	Organism (1)		Diet_(nutrition)	Health (2)
* Disease	Death (1)		Disease	Death (1)
Dog	Pet (1)		Dog	Pet (1)
Dream	God (1)		* Dream	Bed (2)
Eating	Food (1)		Eating	Food (1)
Education	Learning (1)		Education	Learning (1)
Emotion	Experience (1)		Emotion	Sadness (3)
Evolution	Biology (1)		Evolution	Biology (1)
Experience	Time (1)		Experience	Emotion (N/A); Learning (N/A); World (N/A)
Family	Marriage (1)		Family	Marriage (1)
Father	Parent (1)		Father	Parent (1)
Flower	Evolution (1)		Flower	Plant (2)
Food	Eating (1)		Food	Eating (1)
Forest	Tree (1)		Forest	Tree (1)
Friendship	Philosophy (1)		* Friendship	Love (3)
Future	Time (1)		Future	Time (1)
* Goal	Purpose (1)		Goal	Purpose (1)
God	Religion (1)		God	Religion (1)
* Ground	Philosophy (1)		Happiness	Emotion (1)
Happiness	Emotion (1)		Hatred	Emotion (1)
Hatred	Emotion (1)		Health	Physical_fitness (2)
Health	Disease (1)		Heart	Oxygen (N/A); Death (N/A); Organism (N/A)
Hobby	Leisure (1)		* Home	House (2)
Home	Family (1)		Hospital	Bed (N/A); Infant (N/A)
Hospital	Disease (1)		House	Home (2)
House	Family (1)		Human	Animal (9)
Human	City (1)		Infant	Child (1)
Infant	Child (1)		Joy	Happiness (1)
* Joy	Happiness (1)		Learning	Education (2)
Learning	Experience (1)		Leisure	Education (4)
Leisure	Time (1)		Light	Time (1)
Light	Time (1)		Love	Emotion (2)
Love	Family (1)		Marriage	Family (2)
Marriage	Religion (1)		* Money	Bread (N/A)

Table 6.3 part 2 of 2 (started on previous page and continues here).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (position among hyperlinks departing from Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (position among hyperlinks departing from Wikipedia article of start concept)
Money	Water (1)		Mother	Parent (1)
Mother	Parent (1)		Music	Human (N/A); Book (N/A); Pleasure (N/A); Party (N/A); Philosophy (N/A); Test_(assessment) (N/A)
Music	Religion (1)		Nature	Plant (5)
Nature	Human (1)		Old_age	Infant (3)
Old_age	Biology (1)		Organism	Biology (1)
Organism	Biology (1)		Oxygen	Plant (1)
Oxygen	Plant (1)		Paper	Book (1)
Paper	Book (1)		Parent	Father (1)
Parent	Father (1)		* Peace	War (2)
Party	Music (1)		* People	Pet (N/A)
Peace	Education (1)		Pet	Dog (2)
* Pen	Paper (1)		Philosophy	Religion (1)
People	Human (1)		Physical_fitness	Health (1)
Pet	Animal (1)		Plant	Organism (1)
Philosophy	Religion (1)		Pleasure	Emotion (1)
Physical_fitness	Health (1)		Purpose	Goal (1)
Plant	Organism (1)		Rain	Water (1)
Pleasure	Emotion (1)		Religion	Philosophy (1)
Purpose	Goal (1)		Sadness	Emotion (1)
Rain	Water (1)		School	Teacher (1)
Religion	Philosophy (1)		* Sea	Water (1)
Sadness	Emotion (1)		Sibling	Parent (1)
School	Teacher (1)		* Sorrow	Sadness (1)
* Sea	Water (1)		Sport	Adolescence (N/A); Hobby (N/A); Oxygen (N/A)
* Shoe	Clothing (1)		Sun	Oxygen (1)
Sibling	Parent (1)		Teacher	Education (1)
* Sorrow	Sadness (1)		* Telephone	Computer (N/A)
* Sport	Television (1)		Television	Time (N/A); Music (N/A); Adolescence (N/A); Clothing (N/A); Computer (N/A); House (N/A); Leisure (N/A); Light (N/A); Party (N/A); Sport (N/A)
* Summer	Plant (1)		Time	Clock (3)
Sun	Oxygen (1)		* Travel	Water (N/A)
Teacher	Education (1)		Tree	Forest (2)
Test_(assessment)	Education (1)		War	Peace (4)
Time	Religion (1)		Water	Sea (1)
Tree	Oxygen (1)		* Work	Leisure (N/A)
War	Hatred (1)			
Water	Sea (1)			
World	Human (1)			

Table 6.4 part 1 of 2 (starts here and continues on next page). For 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms for departing and arriving hyperlinks (full listing shown in Appendix V). If observed concept has only one departing/arriving hyperlink then observed concept is supplied with an asterisk (*).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)
Adolescence	Child (14)		Adolescence	Child (14)
Animal	Plant (10)		Animal	Plant (10)
Atmosphere_of_Earth	Oxygen (17)		Atmosphere_of_Earth	Plant (4)
* Automobile	Oxygen (2)		Automobile	City (4)
Bed	Hospital (4)		* Bed	Dream (0)
Biology	Organism (57)		Biology	Organism (57)
Birth	Mother (5)		* Birth	Parent (1)
Book	Paper (31)		Book	Paper (31)
Bread	Water (20)		* Bread	Food (17)
Cat	Human (62)		Cat	Pet (22)
Child	Childhood (3)		Child	Childhood (3)
Childhood	Child (26)		Childhood	Child (26)
City	Automobile (2)		* City	Human (1)
Clock	Time (79)		Clock	Time (79)
Clothing	Paper (2); Religion (2)		Clothing	Human (10)
Computer	Telephone (1); Television (1)		Computer	Clock(0); Food(0)
Death	Disease (14)		Death	Disease (14)
Diet_(nutrition)	Health (4)		Diet_(nutrition)	Food (17)
* Disease	Death (1)		Disease	Health (8)
Dog	Pet (19)		Dog	Pet (19)
Dream	Bed(1); God(1)		* Dream	Bed (1)
Eating	Food (14)		Eating	Food (14)
Education	Learning (48)		Education	Learning (48)
Emotion	Experience (12)		Emotion	Human (15)
Evolution	Organism (75)		Evolution	Organism (75)
Experience	Philosophy (2)		Experience	Emotion (1)
Family	Child (51)		Family	Child (51)
Father	Family (12)		Father	Family (12)
Flower	Plant (63)		Flower	Plant (63)
Food	Animal (30)		Food	Health (19)
Forest	Tree (33)		Forest	Tree (33)
Friendship	Love (14)		* Friendship	Love (14)
Future	Time (10)		Future	Time (10)
* Goal	Purpose (1)		Goal	Purpose (1)
God	Religion (20)		God	Religion (20)
* Ground	Philosophy (1)		Happiness	Emotion (8)
Happiness	Emotion (8)		Hatred	Emotion(0); Love(0); Pleasure(0); Sadness(0); War(0)
Hatred	Emotion(0); Happiness(0)		Health	Physical_fitness (10)
Health	Disease (15)		Heart	Oxygen (2)
Hobby	Sport (6)		* Home	House (1)
Home	Family(1); House(1); Love(1)		Hospital	Bed (3)
Hospital	Health (15)		House	Home (12)
House	Home (12)		Human	World (54)
Human	Evolution (72)		Infant	Child (18)
Infant	Child (18)		Joy	Emotion(1); Happiness(1)
* Joy	Happiness (1)		Learning	Education (5)
Learning	Time (6)		Leisure	Education (3)
Leisure	Time (22)		Light	Time (11)
Light	Time (11)		Love	Human (13)
Love	Friendship (8)		Marriage	Family (38)
Marriage	Family (38)		* Money	Bread (0)

Table 6.4 part 2 of 2 (started on previous page and continues here).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)
Money	Water (2)		Mother	Father (3)
Mother	Father (3)		Music	Human (7)
Music	Time (10)		Nature	Plant (31)
Nature	Human (39)		Old_age	Human (2)
Old_age	Biology(1); Child(1)		Organism	Animal (15)
Organism	Plant (12)		Oxygen	Water (41)
Oxygen	Water (41)		Paper	Book (9)
Paper	Book (9)		Parent	Mother (24)
Parent	Mother (24)		* Peace	War (8)
Party	Music (7)		* People	Pet (0)
Peace	War (8)		Pet	Cat (20)
* Pen	Paper (3)		Philosophy	Human (23)
People	Human (5)		Physical_fitness	Health (3)
Pet	Animal (40)		Plant	Food (13)
Philosophy	Religion (7)		Pleasure	Love (2)
Physical_fitness	Health (3)		Purpose	Goal(5); People(5)
Plant	Tree (16)		Rain	Water (14)
Pleasure	Philosophy (3)		Religion	God (18)
Purpose	Happiness(8); Philosophy(8)		Sadness	Emotion (3)
Rain	Water (14)		School	Education (23)
Religion	God (18)		* Sea	Water (9)
Sadness	Emotion (3)		Sibling	Child (32)
School	Education (23)		* Sorrow	Sadness (1)
* Sea	Water (9)		Sport	Adolescence(0); Hobby(0); Oxygen(0)
* Shoe	Clothing (1)		Sun	Light (24)
Sibling	Parent (16)		Teacher	School (22)
* Sorrow	Sadness (1)		* Telephone	Computer (2)
* Sport	Television (4)		Television	Time (6)
* Summer	Plant (1)		Time	Clock (24)
Sun	Oxygen (3)		* Travel	Water (0)
Teacher	School (22)		Tree	Plant (14)
Test_(assessment)	Education (5)		War	Human (23)
Time	Philosophy (26)		Water	Food (26)
Tree	Forest (5)		* Work	Leisure (0)
War	Peace (21)			
Water	Human (27)			
World	Human (5)			

To facilitate identifying possible similarities between frequency distributions of Table 6.5 we transformed for representation of Table 6.6 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of article size for each of 102 core concepts has a weighting parameter 1; scaled frequency distribution of views for each of 102 core concepts has a weighting parameter 0.34; scaled frequency distribution of edits for each of 102 core concepts has a weighting parameter 32.5; and scaled frequency distribution of edits per article size for each of 102 core concepts has a weighting parameter 470000. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 6.5 part 1 of 2 (starts here and continues on next page). Comparison of 102 core concepts based on Wikipedia article statistics: article size (file size in bytes) in end of February 2008, viewing rate in February 2008 (number of views during February 2008), editing rate (number of edits during year 2007) and editing rate per article size (number of edits during year 2007 divided by article size in end of February 2008).

Article size (file size) in end of February 2008 in bytes		Number of views during February 2008		Number of edits during year 2007		Number of edits during year 2007 divided by article size in end of February 2008	
Concept	Bytes	Concept	Views	Concept	Edits	Concept	Edits per article size
Evolution	118194	Love	560808	Evolution	2972	Fun	0.458333333
Cat	88984	Dog	308653	Television	2459	People	0.234086242
Oxygen	78434	Cat	296740	Money	2304	Mother	0.194289261
Sun	77766	Book	268020	Cat	2183	Home	0.167356798
Human	75739	Water	257835	War	2021	Child	0.165239393
Dog	75145	Sun	223969	Music	1935	World	0.159197223
War	69606	Computer	209842	Sun	1905	Television	0.134717581
Time	68785	Evolution	195237	Oxygen	1894	Old_age	0.109980361
Philosophy	66774	Heart	184184	Animal	1871	Pen	0.108827711
Water	63420	Music	183726	Water	1734	Physical_fitness	0.107252014
Marriage	62034	Human	180621	Marriage	1706	Heart	0.107237339
Nature	60605	Animal	179568	Philosophy	1619	Happiness	0.0971965
Computer	58057	Religion	167871	Automobile	1578	Summer	0.083108957
Religion	50637	Television	156359	Book	1566	Money	0.082737817
Music	50062	God	134822	Happiness	1522	Teacher	0.075267464
City	44698	House	132610	Dog	1428	Work	0.074921956
Plant	43161	Philosophy	132590	God	1400	Purpose	0.068502825
Book	40981	Oxygen	128650	Biology	1399	House	0.06661375
Education	37721	Death	121652	People	1368	Animal	0.063436631
Food	37680	Flower	121637	Plant	1332	Environment	0.062946429
Automobile	37300	Plant	118399	Tree	1297	Travel	0.059021922
Bread	37123	Tree	106225	Atmosphere_of_earth	1253	Telephone	0.057976401
Clock	36208	War	105792	Mother	1252	Peace	0.055853211
Biology	35869	Marriage	104131	Telephone	1248	Atmosphere_of_earth	0.053464755
Tree	35572	Automobile	101972	Teacher	1196	Infant	0.053329782
Death	34343	Dream	97321	Time	1196	Shoe	0.051473867
Love	34335	Biology	97177	Dream	1141	Rain	0.050762723
Emotion	33427	Education	96896	Heart	1135	Party	0.048622493
Flower	33338	Management	95452	Death	1109	Eating	0.047850613
Organism	33213	Food	92214	House	1091	Holiday	0.045847176
God	31357	Time	92193	Food	1055	Sport	0.04490985
Light	31244	Light	86018	World	1055	God	0.044647128
Animal	29494	Sport	85181	Shoe	1039	Dream	0.04421281
Money	27847	Telephone	82093	Human	1030	Disease	0.043114583
Hospital	27751	Money	79803	Paper	1009	Automobile	0.04230563
Dream	25807	Emotion	79026	Infant	1001	Health	0.04191376
Family	25451	Disease	72739	Computer	984	Paper	0.041563684
Forest	24923	Family	72685	Light	976	Friendship	0.040647906
Adolescence	24293	Health	65829	Education	975	Birth	0.040327411
Paper	24276	Friendship	59526	Flower	910	Study	0.040277778
Atmosphere_of_Earth	23436	Clothing	59331	Adolescence	865	Biology	0.039003039
Management	23018	Bread	58119	Religion	851	Music	0.038652071
Telephone	21526	Paper	57408	Child	849	Book	0.03821283
Shoe	20185	Adolescence	57314	Love	843	Goodness	0.037037037
Health	19898	Bed	55373	Pen	842	Sea	0.036694826
Chair	19747	City	53793	Health	834	Tree	0.036461262
Clothing	19718	Forest	50638	Sport	817	Diet_(nutrition)	0.035967818
Friendship	19509	Peace	50351	Bread	803	Adolescence	0.035606965
Infant	18770	School	50336	Friendship	793	Death	0.032291879
Television	18253	Happiness	48919	Rain	792	Light	0.031237998
Test_(assessment)	18196	Rain	48337	Peace	761	Plant	0.030861194
Sport	18192	Summer	48255	Clock	750	Clothing	0.03073334
School	16519	World	43439	Disease	701	Bed	0.03038674
House	16378	Home	41882	Party	623	Pet	0.030365087
Disease	16259	Organism	41369	Old_age	616	Pleasure	0.029228687
Teacher	15890	Clock	39217	Clothing	606	War	0.029034853

Table 6.5 part 2 of 2 (started on previous page and continues here).

Article size (file size) in end of February 2008 in bytes		Number of views during February 2008		Number of edits during year 2007		Number of edits during year 2007 divided by article size in end of February 2008	
<i>Concept</i>	<i>Bytes</i>	<i>Concept</i>	<i>Views</i>	<i>Concept</i>	<i>Edits</i>	<i>Concept</i>	<i>Edits per article size</i>
Happiness	15659	Work	38983	Emotion	605	Food	0.027998938
Rain	15602	Holiday	37573	Holiday	552	Father	0.027906598
Learning	14536	Teacher	35626	City	523	Marriage	0.027501048
Pet	14161	Sea	34652	Chair	493	Water	0.027341533
Bed	13756	Nature	34207	Home	485	Flower	0.027296179
Peace	13625	Environment	33546	Management	473	Future	0.027117385
Sibling	13610	Physical_ fitness	31456	Summer	463	Education	0.025847671
Hobby	13582	Pet	30802	Family	462	Evolution	0.0251451
Party	12813	Hospital	28086	Organism	442	Chair	0.024965818
Father	12291	People	27257	Forest	433	Joy	0.024900036
Holiday	12040	Learning	27194	Pet	430	Love	0.024552206
Heart	10584	Sibling	25728	Bed	418	Cat	0.0245325
Leisure	9685	Child	24547	Nature	391	Sun	0.024496567
Goal	9516	Infant	23134	Physical_ fitness	386	Philosophy	0.024245964
Parent	8574	Mother	22343	Hospital	351	Oxygen	0.024147691
Future	8076	Travel	21983	Father	343	Growing	0.022160665
Pen	7737	Birth	21011	School	326	Bread	0.021630795
Sea	7576	Shoe	19289	Learning	282	Clock	0.020713654
World	6627	Future	18688	Sea	278	Management	0.020549135
Sadness	6549	Leisure	18122	Eating	246	School	0.019734851
Mother	6444	Pen	17530	Diet_ (nutrition)	228	Learning	0.01940011
Diet_ (nutrition)	6339	Party	17262	Future	219	Parent	0.019127595
Childhood	6153	Chair	17035	Birth	202	Dog	0.01900326
People	5844	Diet_ (nutrition)	16889	Sibling	179	Hatred	0.018597997
Old_age	5601	Old_age	16508	Parent	164	Family	0.018152528
Summer	5571	Pleasure	15901	Leisure	149	Emotion	0.018099141
Joy	5502	Hobby	15692	Hobby	144	Time	0.017387512
Eating	5141	Sadness	15214	Work	144	Forest	0.01737351
Child	5138	Childhood	14511	Environment	141	Computer	0.016948861
Birth	5009	Hatred	13967	Joy	137	Religion	0.016805893
Experience	4430	Father	12520	Test_ (assessment)	113	Childhood	0.015439623
Pleasure	3695	Purpose	11672	Pleasure	108	Leisure	0.015384615
Physical_ fitness	3599	Experience	11418	Travel	105	Sorrow	0.015151515
Hatred	3495	Goal	9252	Purpose	97	Experience	0.013769752
Home	2898	Eating	7412	Childhood	95	Human	0.013599335
Environment	2240	Joy	7303	Sadness	74	Organism	0.013308042
Work	1922	Fun	6767	Hatred	65	Sibling	0.013152094
Travel	1779	Parent	6580	Experience	61	Hospital	0.012648193
Ground	1467	Ground	4298	Study	29	Living	0.012608353
Purpose	1416	Study	4241	Living	16	City	0.011700747
Living	1269	Sorrow	3780	Goal	15	Sadness	0.011299435
Sorrow	792	Living	3118	Ground	12	Hobby	0.010602268
Study	720	Growing	2594	Sorrow	12	Ground	0.008179959
Growing	361	Goodness	1581	Fun	11	Nature	0.006451613
Goodness	27	Atmosphere_ of_Earth	142	Growing	8	Test_ (assessment)	0.006210156
Fun	24	Test_ (assessment)	0	Goodness	1	Goal	0.001576293

Table 6.6. Degrees of dependency between four rankings of 102 core concepts in respect to following statistical features of Wikipedia articles: article size, views, edits and edits per article size.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
article size for each of 102 core concepts (scaled)	views for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.8221 (null hypothesis Hks not rejected)	gamma=0.609008 (standard error 0.1116137); null hypothesis Hgk rejected (p=4.859052×10 ⁻⁸)	rho= 0.7962692; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.609008; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
article size for each of 102 core concepts (scaled)	edits for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.2919 (null hypothesis Hks not rejected)	gamma=0.5698465 (standard error 0.1156813); null hypothesis Hgk rejected (p=8.392919×10 ⁻⁷)	rho= 0.7487518; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau= 0.5696252; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
article size for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.1625 (null hypothesis Hks not rejected)	gamma=-0.2118035 (standard error 0.1375269); null hypothesis Hgk not rejected (p=0.1235389)	rho=-0.2904083; null hypothesis Hsr rejected (p=0.003172)	tau= -0.2118035; null hypothesis Hkr rejected (p=0.001608)
views for each of 102 core concepts (scaled)	edits for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.22 (null hypothesis Hks not rejected)	gamma=0.6258014 (standard error 0.1098014); null hypothesis Hgk rejected (p=1.202335×10 ⁻⁸)	rho= 0.7961368; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau= 0.6255584; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
views for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.08346 (null hypothesis Hks not rejected)	gamma=0.0277616 (standard error 0.1406653); null hypothesis Hgk not rejected (p=0.8435464)	rho= 0.05822415; null hypothesis Hsr not rejected (p=0.5605)	tau= 0.0277616; null hypothesis Hkr not rejected (p=0.6793)
edits for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.001574 (null hypothesis Hks rejected)	gamma=0.2189625 (standard error 0.1373581); null hypothesis Hgk not rejected (p=0.1109136)	rho= 0.3199792; null hypothesis Hsr rejected (p=0.001044)	tau= 0.2188775; null hypothesis Hkr rejected (p=0.00112)

Based on Table 6.3 and Table 6.4 as well as Appendix J and Table 6.5 we have generated Figure 6.3 that shows *alternative conceptual link structures* formed with 55 concepts belonging to “hyperlink network of 55 concepts” when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including *hierarchy of hyperlinks*, *repetition of hyperlink terms*, *article size*, *viewing rate* and *editing rate per article size*. For each five alternative statistical features considered in subfigures a, b, c, d and e we have supplied each concept primarily with two hyperlinks: *highest-ranking departing hyperlink* and *highest-ranking arriving hyperlink*.

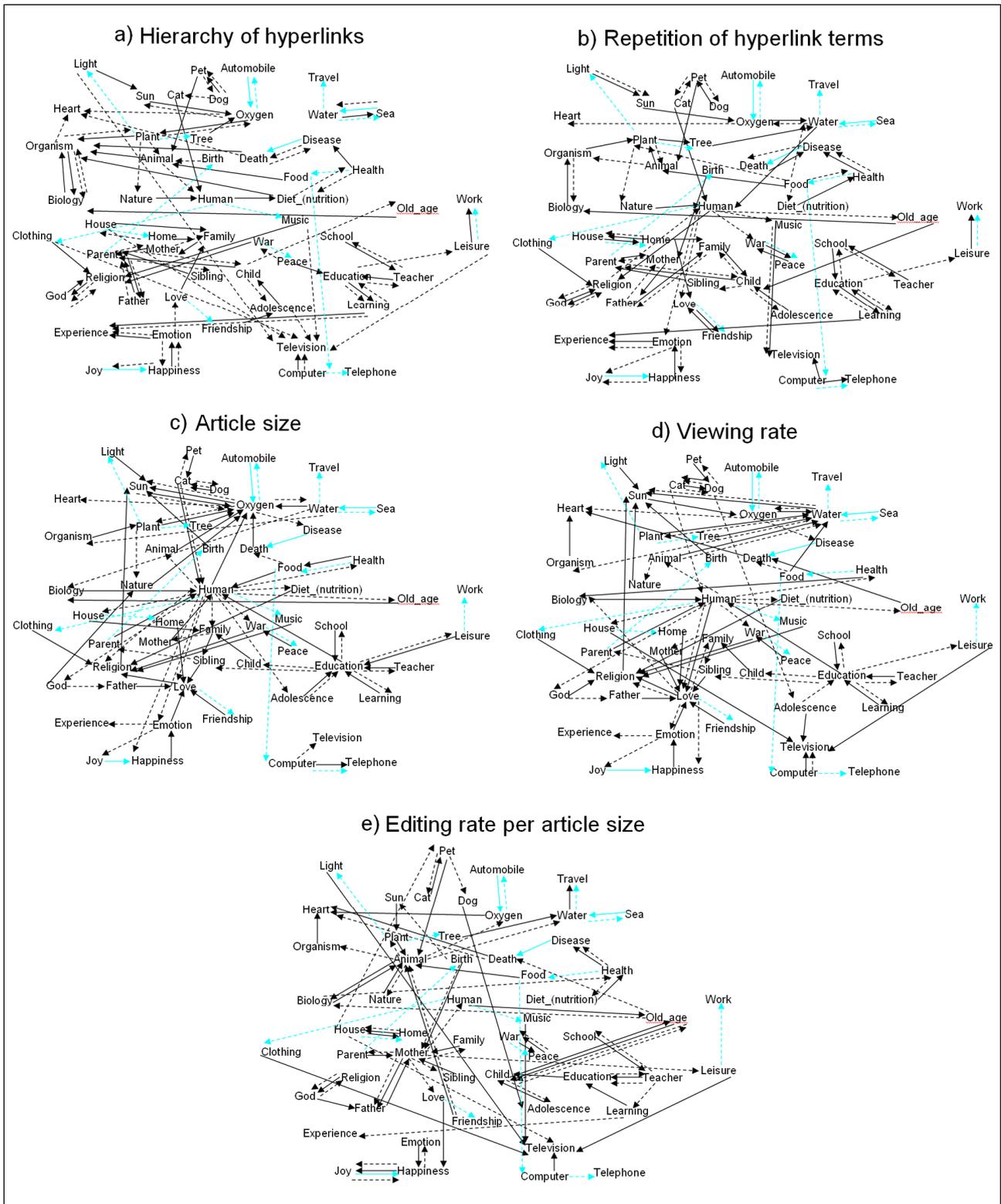


Figure 6.3. Conceptual link structures formed with 55 concepts belonging to “hyperlink network of 55 concepts” when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks (a), repetition of hyperlink terms (b), article size (c), viewing rate (d) and edits per article size (e). Each concept is primarily supplied with two hyperlinks: highest-ranking departing hyperlink indicated with solid line and highest-ranking arriving hyperlink indicated with dotted line. If several links share the position as the highest-ranking link they all are included in the figure as parallel links (for example in subfigure a) both links Emotion->Experience and Learning->Experience arrive at concept Experience). Turquoise lines indicate links that are the sole connecting arriving/departing link for current start/end concept of hyperlink and thus link becomes selected to be also the highest-ranking link (i.e. no alternative connecting links were available when selecting highest-ranking link).

In Figure 6.3 it needs to be noted that the five rankings with two opposite linking directions do not have equal properties and thus comparison of characteristics of conceptual link structures formed based on these ten different approaches can be a bit challenging. Hierarchy of hyperlinks and repetition of hyperlink terms measure statistical features that are present in the start concept of a hyperlink (i.e. on departing side of the hyperlink) whereas article size, viewing rate and editing rate per article size (as well as editing rate itself) measure statistical features that are present in the end concept of a hyperlink (i.e. on arriving side of the hyperlink). Since each concept is primarily supplied with a highest-ranking departing hyperlink and a highest-ranking arriving hyperlink it means that for example in respect to statistical feature “article size” the departing hyperlink of current concept is based on sizes of those articles that are linked to from current concept and the arriving hyperlink of current concept is based on sizes of those articles that link to current concept.

We wanted to better see which concepts in “hyperlink network of 55 concepts” have high level of occurrences as end concepts of arriving hyperlinks or start concepts of departing hyperlinks when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size. To address this we have generated two tables, Table 6.7 shows *most frequently occurring end concepts in highest-ranking departing hyperlinks* in “hyperlink network of 55 concepts” and Table 6.8 shows *most frequently occurring start concepts in highest-ranking arriving hyperlinks* in “hyperlink network of 55 concepts”. It appears that each of five alternative statistical features emphasize concepts somewhat differently thus opening possibilities to gain alternative perspectives to connectivity of concepts in network.

Similarly as in Chapter 5 concerning most actively traversed hyperlinks, we think that various forms of interactive and engaging learning activities can be developed based student’s exploration in hyperlink network along exploration paths that proceed in “hyperlink network of 55 concepts” those arriving or departing hyperlinks that have the highest ranking in respect to each of five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size.

To show some examples we generated a set of ten *learning paths* based on exploration paths in “hyperlink network of 55 concepts” starting from concept Human and *proceeding to highest-ranking end concepts of departing hyperlinks* or *highest-ranking start concepts of arriving hyperlinks* in respect to five alternative statistical features (hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size). Thus based on hyperlinks shown in Figure 6.3 we generated ten learning paths shown in Table 6.9.

Table 6.7. Most frequently occurring end concepts in highest-ranking departing hyperlinks in “hyperlink network of 55 concepts”.

Hierarchy of hyperlinks		Repetition of hyperlink terms		Article size		Viewing rate		Editing rate per article size	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Organism	5	Human	4	Oxygen	9	Love	7	Animal	6
Parent	4	Child	3	Human	6	Religion	6	Mother	5
Religion	4	Family	3	Education	5	Water	6	Television	5
Animal	3	Religion	3	Love	5	Sun	5	Child	3
Family	3	Water	3	Religion	5	Television	4	Happiness	3
Oxygen	3	Animal	2	Sun	4	Education	3	Heart	3
Biology	2	Disease	2	Cat	2	Human	3	Education	2
Education	2	Education	2	Family	2	Death	2	Father	2
Experience	2	Experience	2			Dog	2	Old_age	2
Human	2	Mother	2			Heart	2	Water	2
		Oxygen	2			Oxygen	2		
		Plant	2						
		Television	2						

Table 6.8. Most frequently occurring start concepts in highest-ranking arriving hyperlinks in “hyperlink network of 55 concepts”.

Hierarchy of hyperlinks		Repetition of hyperlink terms		Article size		Viewing rate		Editing rate per article size	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Family	3	Human	9	Human	15	Human	10	Mother	7
Human	3	Education	4	Education	6	Education	6	Animal	5
Pet	3	Cat	3	Oxygen	6	Love	6	Health	3
Plant	3	Family	3	Water	4	Water	6	House	3
Biology	2	Oxygen	3	Cat	3	Dog	3	Old_age	3
Cat	2	Parent	3	Plant	3	Oxygen	3	Teacher	3
Child	2	Plant	3	Computer	2	Animal	2	Birth	2
Computer	2	Water	3	Emotion	2	Cat	2	Child	2
Diet_(nutrition)	2	Emotion	2	Food	2	Computer	2	Happiness	2
Dog	2	Food	2			Emotion	2	Human	2
Emotion	2	Health	2			Food	2	Pet	2
Food	2	House	2			Plant	2	Plant	2
Friendship	2	Light	2					Water	2
God	2	Pet	2						
Happiness	2	Sibling	2						
Health	2								
Home	2								
House	2								
Love	2								
Organism	2								
Oxygen	2								
Parent	2								
Peace	2								
Sibling	2								
Teacher	2								
War	2								
Water	2								

When chaining relation statements of hyperlinks (shown Appendix J) for the learning path for hierarchy of hyperlinks along departing hyperlinks (shown in Table 6.9) we gain a following *educational story* (start concept of hyperlink indicated with italics and end concept of hyperlink with underlining):

Concerning *humans* body size is significantly influenced by environmental factors such as diet.

The *diet* is the sum of food consumed by an organism.

In biology an *organism* is an individual living system.

Based on *biology* all organisms descend from a common ancestor or gene pool.

We think that these ten different types of exploration paths (illustrated with examples in Table 6.9) can provide useful alternative perspectives for adoption of knowledge and acquiring conceptualization about learning topic. Learning paths generated based on exploration paths in respect to different statistical features can highlight different conceptual relationships and structures thus addressing different needs of learning.

As discussed in Chapter 5 concerning most actively traversed hyperlinks, we think that also exploration in respect to different statistical features can offer interesting insight to the student's conceptualization and personal characteristics as well as to the semantical properties of language and consciousness. And also those concepts that belong to repeating cycle that define limits to expansion of exploration path may indicate when generated based on different statistical features some essential properties about semantics and how conceptualization inherently emerges in human mind.

Please note that in our previous analysis discussed in Subchapter 5.3 we encountered similar feature of arriving to a repeating cycle, and we already suggested that this process of arriving to a repeating cycle that we have identified in the Wikipedia (which holds small-world properties (Ingawale et al. 2009)) is related to previous findings of Kinouchi et al. (Kinouchi et al. 2002) that a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step). It can be possible to purposefully avoid entering an eternal cycle in exploration so that when arriving again to a previously visited concept now the learner chooses different ranking method than used previously. So if the learner previously proceeded hyperlinks in hyperlink network in respect to repetition of hyperlink terms he can now instead continue proceeding hyperlinks in respect to article size and thus a new branching emerges to traversed path enabling continuing exploration along yet unexplored hyperlinks.

When comparing ten learning paths generated based on statistical features (shown in Table 6.9) with learning path generated based on relationships of concept maps and learning path generated based on "hyperlink network of 55 concepts" (shown in Chapter 5) it seems that learning paths based on statistical features offer relatively diverse alternatives that emphasize different perspectives than learning path based on relationships of concept maps and learning path based on "hyperlink network of 55 concepts" and arrive to different eternal cycles. There is a need for further experiments with much bigger samples to make more accurate estimates.

Table 6.9. Ten learning paths based on exploration paths in “hyperlink network of 55 concepts” starting from concept Human and proceeding to highest-ranking end concepts of departing hyperlinks or highest-ranking start concepts of arriving hyperlinks in respect to five alternative statistical features (hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size) based on hyperlinks shown in Figure 6.3.

<p><i>Hierarchy of hyperlinks, along departing hyperlinks:</i> Human->Diet_(nutrition)->Organism->Biology->Organism (and then again to Biology thus forming an eternal cycle)</p> <p><i>Hierarchy of hyperlinks, along arriving hyperlinks:</i> Human<-Animal<-Birth<-Parent<-Father<-Parent (and then again to Father thus forming an eternal cycle)</p>
<p><i>Repetition of hyperlink terms, along departing hyperlinks:</i> Human->Religion->God->Religion (and then again to God thus forming an eternal cycle)</p> <p><i>Repetition of hyperlink terms, along arriving hyperlinks:</i> Human<-Religion->God->Religion (and then again to God thus forming an eternal cycle)</p>
<p><i>Article size, along departing hyperlinks:</i> Human->Oxygen->Sun->Oxygen (and then again to Sun thus forming an eternal cycle)</p> <p><i>Article size, along arriving hyperlinks:</i> Human<-Cat<-Dog<-Cat (and then again to Dog thus forming an eternal cycle)</p>
<p><i>Viewing rate, along departing hyperlinks:</i> Human->Love->Religion->Sun->Oxygen->Water->Sun (and then again to Oxygen thus forming an eternal cycle)</p> <p><i>Viewing rate, along arriving hyperlinks:</i> Human<-Cat<-Dog<-Cat (and then again to Dog thus forming an eternal cycle)</p>
<p><i>Editing rate, along departing hyperlinks:</i> Human->Old_age->Child->Old_age (and then again to Child thus forming an eternal cycle)</p> <p><i>Editing rate, along arriving hyperlinks:</i> Human<-Mother<-Birth<-Parent<-Mother (and then again to Birth thus forming an eternal cycle)</p>

In respect to traversing exploration paths in networks shown in Figure 6.3 it could be also possible to select paths so that highest-ranking concepts based on statistical features (shown in Table 6.3, Table 6.4, Table 6.5, Table 6.7 and Table 6.8) could be prioritized even when having distance longer than just one hyperlink. Therefore each concept could be considered metaphorically to have some kind of own gravitational field and the sum of all these gravitational fields would then contribute to selecting at each step the next hyperlink to be traversed next in the hyperlink network.

6.4. Findings and their relation to the entity of the dissertation

The proposed method aims to suggest hyperlink chains that offer highest pedagogic value for the learner’s exploration of hyperlink network of the Wikipedia. An essential strength of the method is the aim to provide a reasonable collection of alternative hyperlink chains that maintain semantic and educational relatedness between each step in the chain and between parallel chains. We think that this is based on four key factors: collaboratively maintained initial organization of concepts and relations (evolution of the Wikipedia), dynamic ranking in respect to five features supporting alternative

perspectives (article statistics), illustrations denoting previous and current conceptual reasoning (concept maps), and letting the learner to make the ultimate decision for next step based on her intuition and consideration (support for variety of personalities).

The proposed method relies heavily on extraction and analysis of hyperlinks in Wikipedia articles related to a chosen learning topic. Recommendable learning paths are represented as a gradually expanding concept map that can be directly shown to the learner and also applied later in various educational purposes. The method aims to provide a balanced tradeoff between extensive coverage and compactness in the generated learning content. The method offers learning paths that should enable the learner to traverse the most essential knowledge in the least amount of time. This traversing can be exploited as means to adopt new knowledge or to refresh it. The traversed learning paths become documented as concept maps thus enabling the learner to analyse illustratively her conceptualization concerning a chosen topic. These knowledge structures can be easily further edited, reused and shared with other learners.

The publication [P3] presents a method naturally extending the method introduced in the publication [P2]. In the method of publication [P2] the learner was offered just a list of hyperlinks in the order of appearance for traversing in hyperlink network but the method of publication [P3] offers also retrieving statistics about Wikipedia articles to offer guidance for exploration in the knowledge structure of the Wikipedia. The exploration method is further extended in publication [P4] by describing how diverse statistics can be taken from the article's usage and edit history to enable the learner to better conceptualize alternative perspectives to the learning topic and their evolution along parallel exploration paths as well as to increase the pedagogical coverage about the learning topic. The exploration paths in the hyperlink network are expected to create concept maps defining useful learning processes. These pieces of knowledge need additional methods to be elaborated to achieve greater educational value. Addressing to this need, publication [P5] describes a wiki architecture to manage knowledge created with collective concept map building and publication [P6] describes a method to connect pieces of conceptual networks to relate the learner's prior knowledge to new knowledge.

Chapter 7. Generating personalized parallel learning paths from the Wikipedia with the latest hyperlink structure or its temporal evolution

In publication [P4] we propose a new method helping the learner to explore and analyze semantic relations between concepts represented by Wikipedia articles by building *parallel, branching learning paths* using adaptive lists and concept maps. We now here first explain basic idea and motivation about generating concept maps based on exploring the *latest version of Wikipedia hyperlink network* and its *temporal evolution*. Then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P4]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P4].

Figure 7.1. illustrates the main idea of the method proposed in publication [P4]. Similarly as in Figure 6.1, also in Figure 7.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. We are extending the proposal made in publication [P3] that used statistics about the hyperlinked articles to create rankings for alternative traversing routes of hyperlinks between articles. Like previously, alternative rankings are represented by three parallel orderings based on Arabic numbers (1., 2., 3.,...), Latin alphabets (a., b., c.,...) and Roman numbers (I, II, III,...). However, instead of just one linear learning path, now we propose building parallel and branching learning paths covering alternative perspectives represented by articles. The learner's exploration path in the hyperlink network so far is shown by a chain of arrows.

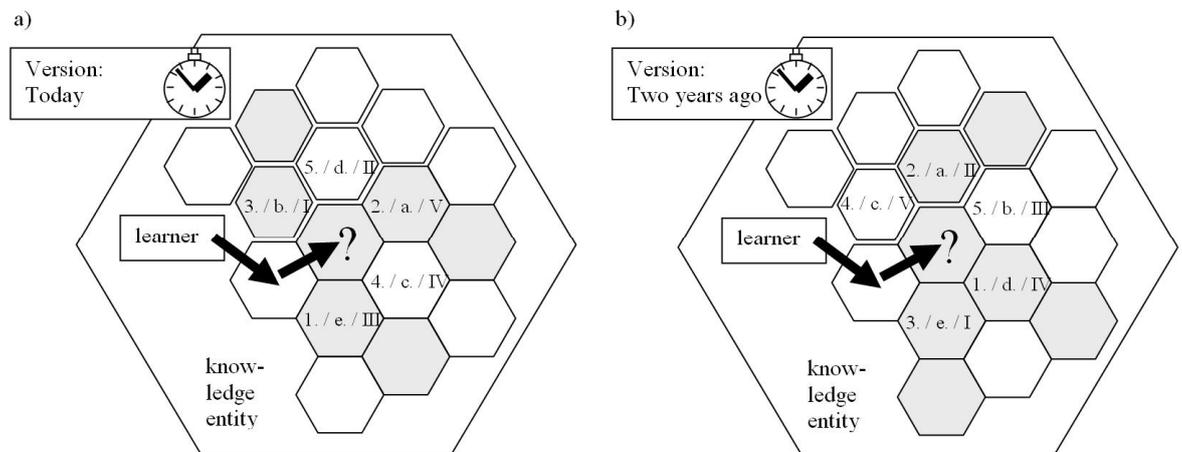


Figure 7.1. Main idea of the method proposed in publication [P4] for generating personalized learning paths from the Wikipedia based on the latest version of hyperlink structure of the Wikipedia (a) or its temporal evolution as illustrated with its two years old temporal version.

In Figure 7.1a, grayed hexagons indicate three possible chains of hyperlinks that the learner can traverse from current article (a hexagon indicated with a question mark) in respect to the latest version of Wikipedia hyperlink network. Each of these three chains is based on a chain of the highest-ranking hyperlinks in respect to one of three shown statistics and is expected to be traversed if learner decides to prioritize ranking values shown in Arabic numbers, Latin alphabets or Roman numbers. In addition, the proposed method also extends support to enable exploring hyperlink networks in any temporal version belonging to the history for the current article. In Figure 7.1b, grayed hexagons indicate three possible exploration paths relying on traversing hyperlinked articles that belong to a chosen temporal version of the hyperlink network based on ranking of article statistics from that same chosen historical moment in time (in this example, two years ago). Each of these three chains is based on a chain of the highest-ranking hyperlink in respect to one of three shown statistics. With different temporal versions of hyperlink networks and their respective rankings the learner can get a great variety of exploration paths to proceed.

7.1. Semantic exploration of network to support knowledge acquisition

Based on our earlier results presented in publication [P3] we identified a need to extend semantically motivated methodology for diverse personalized exploration in the hyperlink network of the Wikipedia. From previous research we found several promising results supporting to develop educational exploration further so that it enables adoption of knowledge through *comparable parallel perspectives* and *temporal versions* along evolution of knowledge structures.

Educational tools providing holistic solutions for everchanging learning scenarios are needed (Utz et al. 2009). As an intuitive medium, concept maps have been recommended for illustrating relationships of educational material in both flexible and compact form (Buzan & Buzan 2003). Knowledge maturing has been verified in the Wikipedia as implicit contextualized knowledge becomes gradually explicitly linked and formalized, and useful measures for maturing can possibly be extracted from creation and usage contexts (Braun & Schmidt 2007).

To exploit the maturing of Wikipedia for pedagogical exploration, our work is inspired by intelligent tutoring systems, content-based filtering, information retrieval and clustering. Weber et al. (Weber et al. 2009) introduced a tool for visual semantic browsing and decision making based on concept maps. García-Plaza et al. (García-Plaza et al. 2008) proposed an unsupervised document representation model to cluster web pages with self-organizing maps using features of the pages. These works support us to develop map-based tool for exploration without extensive indexing of the Web.

Hyperlinks can be seen as a tagging about the article's context. Kamps and Koolen (Kamps & Koolen 2008) showed that the degree of arriving hyperlinks can be exploited to significantly improve effectiveness of ad hoc information retrieval. Zubiaga et al.

(Zubiaga et al. 2009) showed that socially annotated web content can be well classified based on weighted tags, even with limited user counts. Noll and Meinel (Noll & Meinel 2008) showed that tag-based classification seem to suit better to top-level documents in a hierarchy and deeper levels need contextual information mediated from higher levels. These results motivate us to recommend hyperlinks for exploration based on simple ranked statistics about articles that are hierarchically related or encountered earlier.

To address imprecision, Kotsakis (Kotsakis 2006) proposed querying XML documents with fuzzy ranking relying on Levenshtein distances based on tags encountered in paths and characters included in terms. Emphasizing document's structure, Cafarella et al. (Cafarella et al. 2008) proposed querying relational information from HTML tables on the Web and ranking them in respect to diverse text-derived features. To integrate schema information from numerous structured data sources, Nandi and Bernstein (Nandi & Bernstein 2009) proposed a semi-supervised mapping method relying on a log of queries that cause click-throughs. The DBpedia (Bizer et al. 2009) is a promising project extracting structured factual information from Wikipedia articles to form an expressive dataset facilitating queries about relationships and properties. Chan et al. (Chan et al. 2008) proposed a search algorithm over the DBpedia enabling to extract a semantic graph from Wikipedia's hyperlink structure. Another interesting effort to exploit the Wikipedia is semantic search engine NAGA (Kasneji et al. 2008) using graph-based query language with ranking that considers confidence, informativeness and compactness of results.

7.2. Building parallel branching learning paths with temporal versions of hyperlink network

The proposed method relies on using two alternative approaches for learning that are topological exploration mode and evolutionary exploration mode. In *topological exploration mode*, the learner proceeds in the network of hyperlinks belonging to the latest versions of Wikipedia articles. The hyperlinks are shown in a few parallel ranking lists providing alternative rankings sorted in decreasing order of significance. Based on distinct ranking criteria, each list promotes hyperlinks representing a different pedagogical perspective to the learning topic. Despite of relying on our earlier method introduced in publication [P3], now in topological exploration the learner's exploration is expected to give a specific emphasis for building comparable parallel learning paths instead of traversing just linear learning paths.

From the ranking lists the learner selects a desired amount of concepts that seem promising for her, indicating what perspectives she wants to be prioritized by the method in further exploration. Selected concepts and their relations to previous concepts become illustrated in a progressively expanding concept map. Nodes labeled with the concepts are connected with directed arcs labeled with relation statements respectively. From the concept map the learner selects one concept for the next step in exploration and from now on each ranking list shows hyperlinks for the article corresponding to this selected concept. By repeating this cycle, step by step, new hyperlinks with alternative

rankings are constantly recommended by the method thus providing a diversity of parallel and branching exploration paths. Based on her needs and intuition, the learner explores hyperlink network and meanwhile the method builds automatically a concept map that reflects her conceptualization process and enables comparing simultaneously alternative perspectives to the learning topic based on parallel learning paths.

We suggest that ranking of hyperlinks should rely on simple statistics concerning current article and target article. Based on convincing results in our previous work [publication [3]], reflecting five main functions identified for the Wikipedia, we decided to use following measurable parameters as ranking criteria for hyperlinks: order of hyperlinks in current article, hyperlinks whose target article's titles are most repeated in current article, size of hyperlink's target article, view rate of hyperlink's target article and edit rate of hyperlink's target article. These measures can be easily retrieved from revision history and online services providing Wikipedia statistics, and relation statements can be extracted from sentences surrounding hyperlinks with a parsing method, as explained in our previous work in publication [P2] and publication [P3].

In *evolutionary exploration mode* a concept and its relations can be represented by any previous temporal version of the corresponding Wikipedia article and its hyperlinks at that time. The learner is provided with a simple dial to select a desired time frame from the revision history of current article. Also the ranking of hyperlinks is carried out with statistics from the same chosen historical moment in time. The learner can browse consecutive temporal versions of articles to see how new hyperlinks and relation statements are introduced and how older ones become edited or even removed. By observing these temporal transformations the learner can get insight how conceptualization can proceed in a collaborative environment. By alternating between both evolutionary and topological exploration modes, the learner should receive even additional pedagogical advantage as she simultaneously gives attention to both temporal local emergence of knowledge clusters and general connectivity among clusters in relations fixed to a certain time frame.

We propose two optional enhancements for the method that are definition boost and memory effect. *Definition boost* lets the learner to see only those hyperlinks belonging to the introduction section of current article, typically located before the table of contents. Since writing style in introduction is often more definitive than later in the article, also recommended hyperlinks are expected to emphasize now more definitions. *Memory effect* gives extra promotion for hyperlinks that are shared among concepts added so far to the concept map. If at least two previously encountered articles have a same target article as the current article has, this hyperlink will be automatically given a leading position in the ranking lists.

Figure 7.2 (originally published as Figure 1 in publication [P4]) shows a concept map generated with the topological exploration mode starting from Wikipedia article "History of the world" based on the latest version of hyperlink network at the time of writing publication [P4], in January 2010. For each node the linked nodes are based on the highest-ranking hyperlinks, shown in descending order of significance from left to right, while the ranking criteria is based on sum of all five statistical features discussed above. Definition boost was applied on all levels and memory effect was applied only to

generate the nodes of third level. Figure 7.2 shows stubs of concept maps generated with evolutionary exploration mode based on three time frames of article “History of the world” in January 2008 (b), January 2009 (c) and January 2010 (d) with similar conditions for linking nodes as described for the example of topological exploration (a).

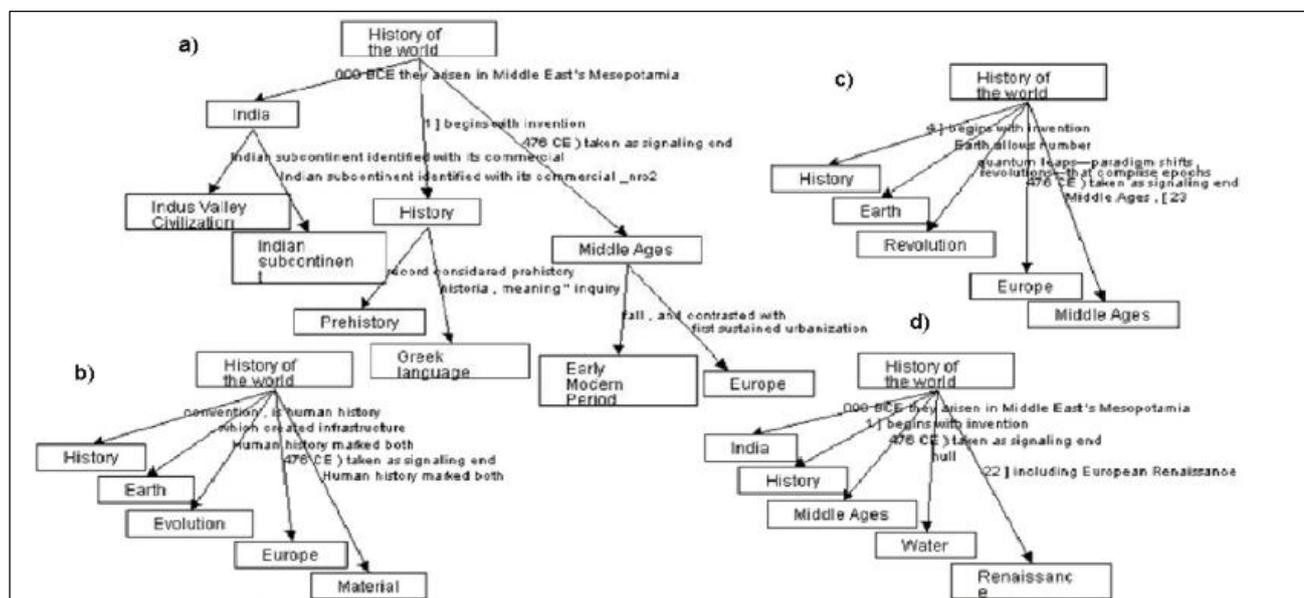


Figure 7.2 (originally published as Figure 1 in publication [P4]). Concept map produced with topological exploration about topic “History of the world” in January 2010 (a). Stubs of concept maps produced with evolutionary exploration about topic “History of the world” with three time frames: January 2008 (b), January 2009 (c), and January 2010 (d).

We carried out experiments to evaluate educational gain of the proposed method. We compared the conceptual structures generated with our method to corresponding established learning material. Comparative analysis done in the context of learning topic of world history showed that learning paths generated with the proposed method in the hyperlink network of the Wikipedia matched well with corresponding learning paths gained when accessing four main periods of history through index of a children’s world history book (Adams 2008).

We made further analysis to get better understanding about *temporal evolution* of hyperlink network of the Wikipedia. Table 7.1 shows Wikipedia articles corresponding to 102 core concepts, from word lists generated by students, listed in chronological order in respect to the creation date of the Wikipedia article.

Table 7.2 offers a comparison of rankings based on *creation date of Wikipedia article*, *occurrences in word lists of students* and *sum of measures of importance given by students* in respect to 55 concepts belonging to “hyperlink network of 55 concepts” when ranking values have been transformed to an equal ranking scale 1–55.

Table 7.1. Wikipedia articles corresponding to 102 core concepts, from word lists generated by students, listed in chronological order in respect to the creation date of the Wikipedia article. Articles created on same day are supplied with suffixes (a, b, c etc.) to indicate their more detailed chronological order, we were not able to find difference in creation time for Health and Pet which both had same creation time at accuracy level of one minute.

<i>Concept</i>	<i>Creation date</i>	<i>Concept</i>	<i>Creation date</i>	<i>Concept</i>	<i>Creation date</i>
Leisure	20010129	Television	20011104	Parent	20020910c
Animal	20010329	Sport	20011105	Birth	20020910d
Plant	20010508	Evolution	20011106a	Adolescence	20020911
Shoe	20010521	Biology	20011106b	Child	20021023
Sea	20010528	Education	20011107	Travel	20021208
Book	20010606	Party	20011108	Future	20021230
Water	20010727	Cat	20011109	Childhood	20030109
Love	20010817	Light	20011110	Pleasure	20030115a
Tree	20010904	Sun	20011111	Happiness	20030115b
Forest	20010909	Marriage	20011112a	Learning	20030215
School	20010910	Music	20011112b	Joy	20030221
Money	20010911	City	20011113	Atmosphere_of_Earth	20030329
Oxygen	20010915	Religion	20011117	Teacher	20030403
Disease	20010919	Hobby	20011118	Eating	20030419
Clock	20010920	Peace	20011122	Test_(assessment)	20030505
Food	20010927	Summer	20011230	Old_age	20030518
Friendship	20010929	Emotion	20020112	Sadness	20030527
Telephone	20010930a	Rain	20020120	Home	20030619
Work	20010930b	Heart	20020127	Chair	20030707
Human	20011003	Bread	20020129a	Experience	20030816
Dog	20011006	Environment	20020129b	Sorrow	20030823
House	20011011	Family	20020204	Sibling	20031029
War	20011015	Clothing	20020207	Growing	20031222
Management	20011016	World	20020211a	Ground	20040113
Death	20011018	Flower	20020211b	Physical_fitness	20040116
Nature	20011025	Health	20020225 (same time shared with Pet)*	Purpose	20040315
God	20011028	Pet	20020225 (same time shared with Health)*	Diet_(nutrition)	20040507
Paper	20011030	Dream	20020318	Study	20040517
Philosophy	20011031a	Fun	20020325	Bed	20040902
Time	20011031b	Hospital	20020803	Living	20041105
Automobile	20011101a	Infant	20020818	People	20051221
Holiday	20011101b	Pen	20020825	Goodness	20060222
Computer	20011102a	Father	20020910a	Hatred	20060911
Organism	20011102b	Mother	20020910b	Goal	20071223

Table 7.2. Comparison of rankings based on creation date of Wikipedia article, occurrences in word lists of students (n=103) and sum of measures of importance given by students (n=103), in respect to 55 concepts belonging to “hyperlink network of 55 concepts”, ranking values transformed to an equal ranking scale 1–55.

Concept	Ranking based on creation date of Wikipedia article	How many positions higher is ranking based on occurrences in word lists of students	How many positions higher is ranking based on sum of measures of importance given by each student	Concept	Ranking based on creation date of Wikipedia article	How many positions higher is ranking based on occurrences in word lists of students	How many positions higher is ranking based on sum of measures of importance given by each student
Leisure	1	-33.5s	-27.5s	Light	29	-5.5s	-9.5s
Animal	2	-7s	-10s	Sun	30	+15s	+15s
Plant	3	-19s	-18s	Music	31	+0.5s	+2.5s
Sea	4	-36s	-43s	Religion	32	+1.5s	-10s
Water	5	-2.5s	0s	Peace	33	-12s	-4
Love	6	+0.5s	+3	Emotion	34	-6s	+4s
Tree	7	-17s	-24s	Heart	35	-5s	+1.5s
School	8	+2.5s	0s	Family	36	+35s	+35s
Oxygen	9	-42.5s	-26s	Clothing	37	+2.5s	+10s
Disease	10	-30s	-44s	Health	38s	+18.5s	+24s
Food	11	+3.5s	+5s	Pet	38s	+3.5s	-3s
Friendship	12	+10s	+10s	Father	39	+4.5s	+15s
Telephone	13	-38.5s	-35s	Mother	40	+12s	+18s
Work	14	+11s	+10s	Parent	41	-10.5s	+5s
Human	15	+5s	+6s	Birth	42	+31s	+32s
Dog	16	-1.5s	-7s	Adolescence	43	-2s	-10
House	17	-0.5s	-3s	Child	44	+29s	+28s
War	18	-27s	-37	Travel	45	-6.5s	+6.5s
Death	19	+15s	+12s	Happiness	46	+22s	+28s
Nature	20	+8s	+9s	Learning	47	+19s	+22s
God	21	-24s	-24.5s	Joy	48	+33s	+31s
Automobile	22	-2s	-11.5s	Teacher	49	-2.5s	-2s
Computer	23	+2s	-3s	Old_age	50	+15.5s	+6s
Organism	24	-27.5s	-26s	Home	51	+38s	+38s
Television	25	-3s	-7s	Experience	52	+12s	+12s
Biology	26	-19s	-23s	Sibling	53	+1.5s	+1
Education	27	+7.5s	+8	Diet_(nutrition)	54	+2.5s	+11s
Cat	28	+2s	-17.5s				
<i>(the listing continues on the fifth column of this table)</i>							

Based on Table 7.2 for each of three comparison tests Table 7.3 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between three rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to creation date of Wikipedia article, occurrences in word lists of students and sums of measures of importance given by students.

Table 7.3. Degrees of dependency between three rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to creation date of Wikipedia article, occurrences in word lists of students (n=103) and sums of measures of importance given by students (n=103).

Compared pair of distributions		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
creation date of Wikipedia article for each of 55 concepts	occurrences in word lists of students for each of 55 concepts (n=103)	gamma=0.2380952 (standard error 0.1920267); null hypothesis Hgk not rejected (p=0.2150099)	rho=0.321374; null hypothesis Hsr rejected (p=0.01674)	tau=0.2317536; null hypothesis Hkr rejected (p=0.01464)
creation date of Wikipedia article for each of 55 concepts	sums of measures of importance given by students for each of 55 concepts (n=103)	gamma=0.1540541 (standard error 0.1904736); null hypothesis Hgk not rejected (p=0.4186333)	rho=0.2380446; null hypothesis Hsr not rejected (p=0.0801)	tau=0.1537943; null hypothesis Hkr not rejected (p=0.09784)
occurrences in word lists of students for each of 55 concepts (n=103)	sums of measures of importance given by students for each of 55 concepts (n=103)	gamma=0.7863248 (standard error 0.1222799); null hypothesis Hgk rejected (p=1.271583×10 ⁻¹⁰)	rho=0.9042751; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.7645224; null hypothesis Hkr rejected (p=8.882×10 ⁻¹⁶)

Table 7.4 shows some of the greatest and smallest ranking differences for rankings based on creation date of Wikipedia article, occurrences in word lists of students and sum of measures of importance, in respect to 55 concepts belonging to “hyperlink network of 55 concepts”. It appears that concepts having higher ranking position for occurrences in word lists generated by students or for sum of measures of importance given by each student than for creation date of Wikipedia article include for example Home, Family, Joy, Birth and Child. In addition, concepts having higher ranking position for creation date of Wikipedia article than for occurrences in word lists generated by students or for sum of measures of importance given by each student include for example Sea, Disease, Telephone and Leisure.

Concepts in hyperlink network of the Wikipedia have a varying emphasis in respect to what is the balance of departing and arriving hyperlinks they have. We think that analysis about balance of departing and arriving hyperlinks can fruitfully help to gain better understanding and modeling about how in conceptual networks such exploration paths could be identified that are educationally most rewarding to become explored by a student. To enable analysing the role of each concept has in respect to *balance of departing and arriving hyperlinks* Table 7.5 shows difference between the number of departing hyperlinks and the number of arriving hyperlinks inside hyperlink network of 102 core concepts and inside “hyperlink network of 55 concepts”, shown in decreasing order of size of difference.

It seems to us that there can be some general characteristics about a concept that affects the balance of its departing and arriving hyperlinks. If trying to coarsely contrast opposite sides, it seems that a Wikipedia article that has more departing hyperlinks than arriving hyperlinks can perhaps be considered to represent topics that remain on relatively informal level of language whereas a Wikipedia article that has less departing hyperlinks than arriving hyperlinks can perhaps be considered to represent topics that deal with systematical classification. This hypothesis seems to get some support when comparing conceptual pairs about approximately same topic that have contrasting emphasis in balance of departing and arriving hyperlinks, for example in respect to hyperlink network of 102 core concepts Nature has a positive balance value 5 (10-5=5)

whereas Organism has negative balance value -6 ($4-10=-6$), and furthermore Animal has neutral balance value 0 ($10-10=0$). It seems that limiting analysis to a smaller hyperlink network containing only 55 concepts instead of 102 concepts can cause changes in balance of departing and arriving hyperlinks, for example Birth gets higher relative position in ranking based on balance value in network of 55 concepts than in network of 102 concepts, and similarly Oxygen gets lower position in ranking.

Table 7.4. Some of the greatest and smallest ranking differences for 55 concepts belonging to “hyperlink network of 55 concepts” in respect to occurrences in word lists generated by students ($n=103$) versus creation date of Wikipedia article, and in respect to sum of measures of importance given by each student ($n=103$) versus creation date of Wikipedia article, ranking values transformed to equal ranking scale 1–55.

Comparison between creation date of Wikipedia article and occurrences in word lists of students			Comparison between creation date of Wikipedia article and sum of measures of importance given by students		
Some of the greatest ranking differences for concepts having higher ranking position for occurrences in word lists generated by students than for creation date of Wikipedia article	Some of the greatest ranking differences for concepts having lower ranking position for occurrences in word lists generated by students than for creation date of Wikipedia article	Some of the smallest ranking differences for concepts between ranking based on occurrences in word lists generated by students and creation date of Wikipedia article	Some of the greatest ranking differences for concepts having higher ranking position for sum of measures of importance given by each student than for creation date of Wikipedia article	Some of the greatest ranking differences for concepts having lower ranking position for sum of measures of importance given by each student than for creation date of Wikipedia article	Some of the smallest ranking differences for concepts between ranking based on sum of measures of importance given by each student and creation date of Wikipedia article
Home (+38s)	Oxygen (-42.5s)	Love; Music (+0.5s)	Home (+38s)	Disease (-44s)	School; Water (0s)
Family (+35s)	Telephone (-38.5s)	House (-0.5s)	Family (+35s)	Sea (-43s)	Sibling (+1)
Joy (+33s)	Sea (-36s)	Religion; Sibling (+1.5s)	Birth (+32s)	War (-37)	Heart (+1.5s)
Birth (+31s)	Leisure (-33.5s)	Dog (-1.5s)	Joy (+31s)	Telephone (-35s)	Teacher (-2s)
Child (+29s)	Disease (-30s)	Cat; Computer (+2s)	Child; Happiness (+28s)	Leisure (-27.5s)	Music (+2.5s)
		Adolescence; Automobile (-2s)			

We think that the *chronological order of adding new hyperlinks* to a Wikipedia article can offer useful insight about how humans prioritize certain relationships when they collectively gradually build a hyperlink network cross-linking various concepts.

Table 7.6 shows three chronologically first hyperlinks added before March 2005 to Wikipedia articles corresponding to 102 core concepts that link to an article corresponding to any of 102 core concepts. Based on Table 7.6, four lists in Table 7.7 summarizes most occurring concepts among three first added hyperlinks and only in the first added hyperlink, and enables to contrast observation inside hyperlink network of 102 core concepts and observation inside “hyperlink network of 55 concepts”. Although differences are small, highest-ranking concepts seem to deal a lot with topics related to religion and nature, and when limiting analysis from the first three hyperlinks to only the first hyperlink seems to increase occurrences of Human and when limiting vocabulary from 102 to 55 concepts seems increase occurrences of Education.

Table 7.5. Difference between the number of departing hyperlinks and the number of arriving hyperlinks inside hyperlink network of 102 core concepts and inside “hyperlink network of 55 concepts”, shown in decreasing order of size of difference. Duplicates have been eliminated from the number of hyperlinks (i.e. if a Wikipedia article contains several hyperlinks pointing to a certain other Wikipedia article only one occurrence of this hyperlink is counted).

Inside hyperlink network of 102 core concepts (* = concept belongs to “hyperlink network of 55 concepts”)				Inside “hyperlink network of 55 concepts”	
Concept	How much more departing hyperlinks than arriving hyperlinks	Concept	How much more departing hyperlinks than arriving hyperlinks	Concept	How much more departing hyperlinks than arriving hyperlinks
Hobby	8 (8-0)	Goodness	0 (0-0)	Food	9 (10-1)
Food*	7 (12-5)	Ground	0 (0-0)	Human	5 (16-11)
Human*	6 (20-14)	Growing	0 (0-0)	Education	4 (10-6)
Atmosphere_of_Earth	5 (9-4)	Holiday	0 (0-0)	Birth	3 (4-1)
Nature*	5 (10-5)	Hospital	0 (2-2)	Nature	3 (7-4)
Education*	4 (13-9)	Living	0 (0-0)	Death	2 (7-5)
Pleasure	4 (7-3)	Management	0 (0-0)	Friendship	2 (3-1)
Test_(assessment)	4 (4-0)	Sea*	0 (1-1)	Home	2 (3-1)
Bed	3 (3-0)	Study	0 (0-0)	House	2 (4-2)
Birth*	3 (4-1)	War*	0 (4-4)	Mother	2 (7-5)
Bread	3 (4-1)	Adolescence*	-1 (7-8)	Parent	2 (6-4)
Death*	3 (9-6)	Dream	-1 (0-1)	Water	2 (8-6)
Friendship*	3 (4-1)	Experience*	-1 (2-3)	Cat	1 (3-2)
Mother*	3 (8-5)	Goal	-1 (1-2)	Child	1 (6-5)
Party	3 (3-0)	Health*	-1 (5-6)	Clothing	1 (2-1)
People	3 (4-1)	Joy*	-1 (1-2)	Computer	1 (2-1)
Sadness	3 (6-3)	Marriage	-1 (8-9)	Dog	1 (3-2)
Child*	2 (9-7)	Rain	-1 (3-4)	Emotion	1 (4-3)
City	2 (3-1)	School*	-1 (2-3)	God	1 (3-2)
Clock	2 (3-1)	Sorrow	-1 (0-1)	Leisure	1 (5-4)
Eating	2 (5-3)	Telephone*	-1 (0-1)	Light	1 (2-1)
Emotion*	2 (8-6)	Travel*	-1 (0-1)	Music	1 (2-1)
Forest	2 (4-2)	Work*	-1 (0-1)	Old_age	1 (4-3)
Home*	2 (3-1)	Automobile*	-2 (1-3)	Peace	1 (2-1)
Learning*	2 (4-2)	Biology*	-2 (9-11)	Teacher	1 (3-2)
Leisure*	2 (8-6)	Childhood	-2 (4-6)	Tree	1 (2-1)
Parent*	2 (6-4)	Future	-2 (0-2)	Automobile	0 (1-1)
Purpose	2 (4-2)	God*	-2 (4-6)	Diet_(nutrition)	0 (4-4)
World	2 (2-0)	Oxygen*	-2 (9-11)	Father	0 (5-5)
Cat*	1 (3-2)	Paper	-2 (2-4)	Health	0 (4-4)
Clothing*	1 (4-3)	Sibling*	-2 (6-8)	Learning	0 (2-2)
Dog*	1 (3-2)	Sport	-2 (1-3)	Pet	0 (3-3)
Father*	1 (6-5)	Heart*	-3 (0-3)	Plant	0 (8-8)
House*	1 (4-3)	Music*	-3 (3-6)	Sea	0 (1-1)
Infant	1 (6-5)	Physical_fitness	-3 (0-3)	Animal	-1 (7-8)
Light*	1 (3-2)	Disease*	-4 (1-5)	Joy	-1 (1-2)
Love*	1 (11-10)	Plant*	-4 (12-16)	Love	-1 (6-7)
Money	1 (2-1)	Time	-4 (8-12)	School	-1 (2-3)
Old_age*	1 (6-5)	Evolution	-5 (5-10)	Telephone	-1 (0-1)
Peace*	1 (2-1)	Happiness*	-5 (2-7)	Travel	-1 (0-1)
Pen	1 (1-0)	Hatred	-5 (0-5)	War	-1 (3-4)
Pet*	1 (4-3)	Sun*	-5 (2-7)	Work	-1 (0-1)
Shoe	1 (1-0)	Family*	-6 (6-12)	Adolescence	-2 (4-6)
Summer	1 (1-0)	Organism*	-6 (4-10)	Experience	-2 (0-2)
Teacher*	1 (4-3)	Religion*	-7 (5-12)	Happiness	-2 (2-4)
Tree*	1 (3-2)	Television*	-10 (0-10)	Sibling	-2 (5-7)
Water*	1 (10-9)	Philosophy	-11 (3-14)	Biology	-3 (6-9)
Animal*	0 (10-10)			Disease	-3 (1-4)
Book	0 (2-2)			Heart	-3 (0-3)
Chair	0 (0-0)			Oxygen	-3 (6-9)
Computer*	0 (2-2)			Organism	-4 (3-7)
Diet_(nutrition)*	0 (4-4)			Religion	-4 (3-7)
Environment	0 (0-0)			Sun	-4 (2-6)
Flower	0 (2-2)			Family	-5 (5-10)
Fun	0 (0-0)			Television	-7 (0-7)
<i>(the listing continues on the third column of this table)</i>					

Table 7.6 part 1 of 2 (starts here and continues on next page). Three chronologically first hyperlinks added before March 2005 to Wikipedia articles corresponding to 102 core concepts that link to an article corresponding to any of 102 core concepts.

Wikipedia article	Three chronologically first hyperlinks added before March 2005 that link to an article corresponding to any of 102 core concepts (* = several hyperlinks added at the same time in one instance of article revision; p = previous instance of article revision included already this second/third hyperlink; x = no hyperlinks added before March 2005)		
<i>Article title (concept)</i>	<i>First hyperlink</i>	<i>Second hyperlink</i>	<i>Third hyperlink</i>
Adolescence	Child	Education; School	p
Animal	Human	Cat; Dog *	p
Atmosphere_of_Earth	Oxygen; Sun *	p	Rain
Automobile	Travel		
Bed	Infant		
Biology	Evolution	Environment; Organism *	p
Birth	Death; Mother *	p	Sun
Book	Paper		
Bread	Food; Water *	p	
Cat	Dog	Pet	Rain
Chair	Music		
Child	Human	Parent	Tree
Childhood	Child		
City	Religion		
Clock	Time	Computer	
Clothing	Animal	God	Shoe
Computer	Telephone	Clock	
Death	Heart	Birth	Religion
Diet_(nutrition)	Food		
Disease	Biology		
Dog	Pet	Death	Cat
Dream	God	Experience	
Eating	Food		
Education	Family	School	Child
Emotion	Joy; Sadness *	p	
Environment	Biology	Light; Water *	p
Evolution	Biology	God	Organism
Experience	Time		
Family	Marriage	Father; Mother *	p
Father	Mother	Marriage	Family
Flower	Plant	Death; Love *	p
Food	Animal; Plant *	p	Bread
Forest	Tree		
Friendship	x		
Fun	x		
Future	Death; Evolution; God; Human; Philosophy; Religion; Time *	p	p
Goal	x		
God	Philosophy	Evolution	
Goodness	Sun		
Ground	Philosophy	Music	
Growing	x		
Happiness	Money	Family; Food; Learning; Love; Philosophy; Religion *	p
Hatred	x		
Health	Human; Organism *	p	Biology
Heart	Oxygen; Water *	p	Animal
Hobby	Sport		

Table 7.6 part 2 of 2 (started on previous page and continues here).

Wikipedia article	Three chronologically first hyperlinks added before March 2005 that link to an article corresponding to any of 102 core concepts (* = several hyperlinks added at the same time in one instance of article revision; p = previous instance of article revision included already this second/third hyperlink; x = no hyperlinks added before March 2005)		
<i>Article title (concept)</i>	<i>First hyperlink</i>	<i>Second hyperlink</i>	<i>Third hyperlink</i>
Holiday	Travel	Religion	Summer
Home	x		
Hospital	Disease	Health	
House	Human	Music	Animal
Human	Evolution	Cat; Child; Environment *	p
Infant	Child	Health	Birth
Joy	Happiness	Emotion	
Learning	Education		
Leisure	Sport	Education	
Light	Time	Sun	
Living	x		
Love	Emotion	Family	God
Management	x		
Marriage	Religion	Family	Emotion
Money	Paper	Bread	
Mother	Father	Child; Parent *	p
Music	Television	Religion	
Nature	Biology	God	Education
Old_age	Death	Biology	
Organism	Animal; Biology; Plant *	p	p
Oxygen	Water	Plant	
Paper	Tree	Book	Forest
Parent	x		
Party	Family; Holiday *	p	Marriage
Peace	War		
Pen	x		
People	x		
Pet	Cat; Dog *	p	People
Philosophy	Goodness	God; Time *	p
Physical_fitness	Health		
Plant	Flower; Tree *	p	Organism
Pleasure	Happiness		
Purpose	x		
Rain	Water	Sun	
Religion	God	War	Philosophy
Sadness	x		
School	Education	Learning	
Sea	x		
Shoe	Clothing; Home *		
Sibling	x		
Sorrow	x		
Sport	x		
Study	x		
Summer	x		
Sun	Oxygen	Water	
Teacher	Education; School *	p	
Telephone	Ground		
Television	Computer		
Test_(assessment)	Education	Computer	Music; Teacher *
Time	Clock	Leisure; Travel *	p
Travel	x		
Tree	Forest; Religion; Water *	p	p
War	Religion	Peace	Philosophy
Water	Sea	Biology	Oxygen
Work	x		
World	Religion	Philosophy	Birth

Table 7.7. Most occurring concepts among three first added hyperlinks and only in the first added hyperlink when observed inside hyperlink network of 102 core concepts and “hyperlink network of 55 concepts”.

Inside hyperlink network of 102 core concepts		Inside “hyperlink network of 55 concepts”	
<i>Most occurring concepts among three first added hyperlinks</i>	<i>Most occurring concepts only in the first added hyperlink</i>	<i>Most occurring concepts among three first added hyperlinks</i>	<i>Most occurring concepts only in the first added hyperlink</i>
Religion (10)	Religion (6)	Biology; Education; Religion (6)	Human (4)
Biology; God (8)	Biology; Human; Water (5)	Animal (5)	Animal; Biology; Education; Religion; Water (3)
Education; Philosophy; Water (7)	Education; Time (4)	Cat; Child; Family; God; Human; Water (4)	Death; Dog; Mother; Oxygen; Plant (2)

7.3. Findings and their relation to the entity of the dissertation

In our previous work discussed in publication [P3] we identified usefulness of supporting the learner’s exploration in the hyperlink network of the Wikipedia by ranking hyperlinks in respect to the article’s usage and edit history. We previously noted the advantage of generating alternative hyperlink chains that maintain semantic and educational relatedness between each step in the chain and between parallel chains. Now in publication [P4] we want to incorporate simultaneous visualization and exploration of parallel hyperlink chains paths for the actual learning process in adoption of knowledge.

Even a short chain of hyperlinks in the Wikipedia can cover essential knowledge about a desired educational topic. Due to rich variety of contributors, the hyperlink network of the Wikipedia combines numerous individually favored relations between concepts into one browsable entity. However, it is hard to define requirements for optimal exploration paths that can be favorably personalized in diverse contexts and generated with limited computational load. Results of related research that has been discussed earlier in this Chapter 7 (as well as in publication [P4]) has indicated that simple quantitative semi-automatic methods can be successfully used for measuring matching with imprecise queries to rank documents in a collection. This suggests that desired educational perspectives can be efficiently promoted by chaining ranked hyperlinks that have even relatively imprecise correlation between a simple statistical feature of current and target article. To enable holistic adaptive conceptualization process, the learner needs interactive knowledge representations and concept maps seem to offer an efficient medium for compact yet flexible illustrations. By approaching the learning topic simultaneously along parallel alternative exploration paths, the learner is expected to acquire rich complementing perspectives to adopt new knowledge.

Besides exploring just the relations between the latest versions of articles, browsing consecutive temporal versions of an article enables analyzing emergence of knowledge clusters. Two additional options enable to favor hyperlinks that have previously

encountered target articles and hyperlinks that promote definitions. Initial experiments with a prototype indicate that proposed functional principles can fruitfully support exploration that is sustainable for human learning.

We think that publication [P4] continues the development of method introduced in publication [P3] like that work was an extension from the method of publication [P2]. This development relies on suggesting certain statistics as guidance for exploration but we think that our proposal should be seen as a promising example for broader generalizations as well to achieve increased pedagogic coverage on educational exploration.

The method of publication [P4] can be seen as an attempt to form general approach for constructing educational knowledge in the form of concept maps by taking inspiration from the knowledge structure of the Wikipedia.

Along research of publication [P4] we identified a need for future research to address agglomeration of separate learning tasks and complementing methods of collaboration. We considered that easy evaluation and intervention methods are needed for teachers and furthermore personal learning styles and special needs should be strongly supported with encouragement and inspiration. Motivated by these notions we decided to augment the method of publication [P4] by introducing in publication [P5] a wiki architecture that helps to agglomerate individually created pieces of knowledge and in publication [P6] a method to find the shortest paths between pieces of knowledge between the learner's knowledge and the learning objective with support from learning context.

Part IV: Connecting and agglomerating entities of collaborative knowledge resources based on personal contributions

Chapter 8. A wiki framework to support collaborative knowledge building process with concept maps

In publication [P5] we propose a new educational framework, ConceptMapWiki, to generate collaboratively *reusable evolving knowledge resources* for education based on an inter-connected diverse collection of partially overlapping *concept maps*, thus forming shared ontologies. ConceptMapWiki is a wiki based on a method representing knowledge with adaptive concept maps that are collaboratively created, edited and browsed according to various learner-driven criteria for many educational purposes, supplied with collaboratively defined and evaluated learning paths.

We now here first explain basic idea and motivation about using a collaborative *educational wiki framework* for building collection of concept maps and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P5]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P5]. Figure 8.1 illustrates the main idea of the method proposed in publication [P5].

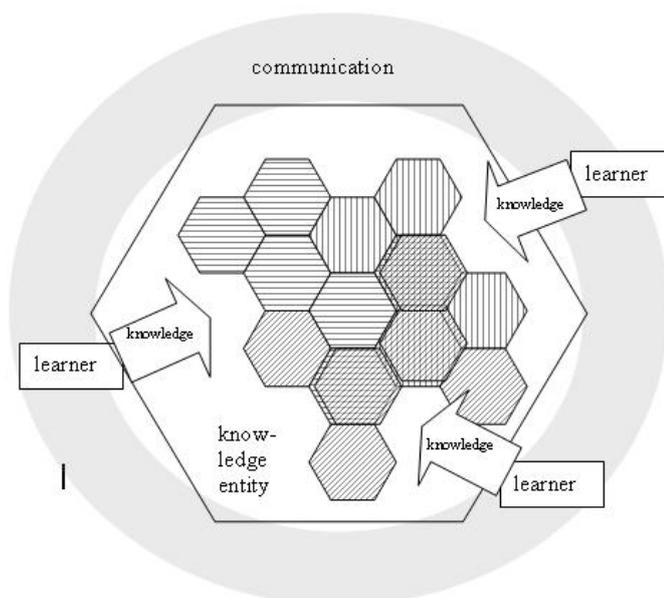


Figure 8.1. Main idea of the method proposed in publication [P5] for wiki framework to support collaborative knowledge building process with concept maps.

Similarly as in Figure 4.1, also in Figure 8.1 the linked hexagons together represented a collectively generated conceptual network. However now this network is not anymore a single concept map but instead a collectively gradually built collection of concept maps. Each joint group of hexagons indicated with a line pattern in specific direction (horizontal, vertical or ascending diagonal) represents a concept map created by a single collaborating learner. Overlapping concept maps introduce some hexagons having several concurrent line patterns. The collaborating learners contribute by building and editing together a progressively growing, complementing and finetuning knowledge entity of conceptual network. Communication is carried out between all collaborators to agree about actions to be taken during the building process.

Motivated by the methods introduced in publications [P2], [P3] and [P4] to guide educational exploration in hyperlink network of the Wikipedia, we identified that similar approach could be fruitfully applied with collaboratively built concept map collection. As an additional advantage, the proposal of publication [P5] seemed to usefully enable to developing collaborative framework addressing needs we had identified in publication [P1].

8.1. Collective construction of knowledge structures

Collaborative construction of concept maps has been shown to assist learning knowledge structures (Schaal et al. 2009) and efficient graph-theoretic reasoning algorithms enable relating general problem solving processes to fundamental problems in computer science (Chein & Mugnier 2009). Also graph-based clustering schemes have been used to identify groups of related tags in folksonomies (Papadopoulos et al. 2010). Since emerging in both social networks and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009), small-world networks are a promising structure for representing educational knowledge. Methods developed to model and explore knowledge in the Wikipedia give inspiration for developing pedagogically motivated knowledge repositories based on resembling wiki frameworks to support collaboratively various personalized learning tasks as discussed in publication [P4] and Chapter 7. Having over 4.3 million articles (as of June 2013) in English, more than concepts in a typical human vocabulary (Moore & ten Bosch 2009), the full content of Wikipedia cannot be effectively evaluated all the time (Milne 2009) and thus it seems reasonable to generate guidance for exploration by evaluating only few steps further in the knowledge network.

Learners should be enabled to retrieve personalized information with semantically enriched models (Zhuhadar et al. 2009). When different parties provide mappings with typed links between data, semantic cohesion can increase thus enabling data integration on global scale (Bizer et al. 2009). For example, Semantic MediaWiki enables annotating wikis with semantic data and OntoWiki offers intuitive authoring and navigating of RDF-based knowledge bases. 24 basic and compound evolution patterns of the knowledge engineering process have been identified for knowledge bases in the semantic web (Rieß et al. 2010). Ontology evolution has been guided by pattern

modeling and quality evaluation (Djedidi & Aufaure 2010) and ontology mapping has been used for open-corpus personalization in students' knowledge assessments (Sosnovsky 2009). Ontologies can be used for modeling educational modules (Borges & Barbosa 2009) and a collaborative environment using shared ontologies can be explored with concept maps (Leblanc & Abel 2009). Standardized concept map representation Topic Maps can address knowledge resources on multiple levels (Li et al. 2010) and enable forming an ontology for acquired knowledge in a lifelong learning perspective (Lavik et al. 2006). Using a wiki visualized with Topic Maps test users went through significantly less irrelevant information and pages than with a traditional wiki (Espiritu et al. 2006). An interactive workspace can integrate real-time synchronized wiki collaboration in knowledge-building activities based on concept mapping (Baraldi et al. 2006). There are many semi-automatic approaches to build concept maps (Kowata et al. 2010).

8.2. Wiki of concept maps for pedagogic knowledge management

In publication [P5] we propose a wiki based on method of representing knowledge collaboratively with concept maps. The method relies on contributions from individual learners and educators generating educational content by drawing concept maps into a graphic Java-driven user interface with an aim to capture some core semantic meanings of the learning topic relatively intuitively and spontaneously. Each step of creating, editing or browsing a concept map are recorded via Java Database Connectivity (JDBC) interface in a compact text format into a relational MySQL database as *concept map objects* with time stamps and a user profile, containing background information about the contributor's role, gender, age, educational level and experience in current topic. All the concept map objects together form a *concept map collection* that cumulatively matures due to collaborative editing and can be explored and exploited by the learners in various personalized guided learning activities addressing various perspectives and levels of detail.

Figure 8.2 (originally published as Figure 1 in publication [P5]) shows an example how concept maps and learning paths can be represented to the learner in browsing. Size of concepts and width of arcs indicate the collaboratively defined ranking, in decreasing order of significance.

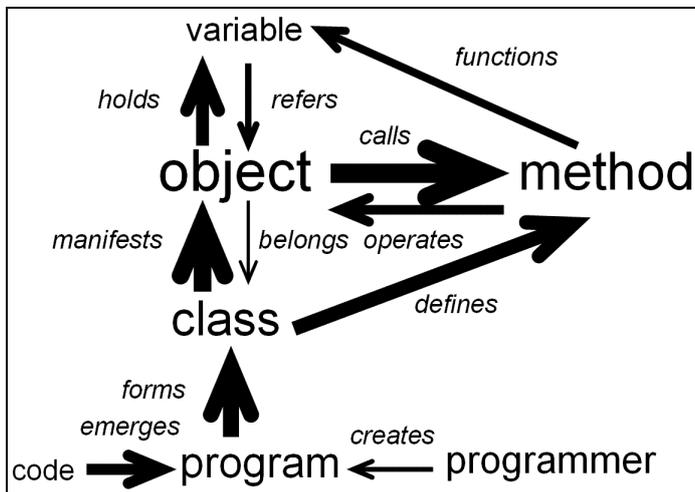


Figure 8.2 (originally published as Figure 1 in publication [P5]). Example of representation of concept maps and learning paths..

Learning activities offered by the method rely on two basic modes of browsing. In *topological view* the learner browses conceptual relationships in a certain concept map or between a group of related concept maps in a frozen time frame chosen by the learner, often the latest version. In *temporal view* the learner browses temporal versions of a concept map or a group of related concept maps in sequential time frames showing how the maps gradually evolve and get edited. These two views are generated by querying the database of concept map objects with edit histories. In addition, the method enables creating and editing user-defined learning paths based on certain parts of the conceptual relationship network in the concept map collection. A *learning path* for a desired learning topic primarily consists of a set of concepts and relationships considered pedagogically valuable to be explored to support adoption of knowledge about the topic. The creation, editing and browsing of learning paths by the learners and educators is performed and recorded similarly as done with concept maps, supplied with recommendations about useful order and priority of exploring conceptual relationships supported by various sequential, branching and looping constellations.

As the learner browses the concept maps and learning paths from concept to concept about learning topic she aims to adopt, she becomes fruitfully exposed to various complementing perspectives. To enable diverse alternative perspectives the connectivity between concepts can be generated and adjusted based on various *relatedness criteria* concerning shared concepts and arcs, including high occurrence in concept maps or collaborative edit histories, popularity of being explored or included in learning paths, as well as quality of ratings or annotations given by the user community. In respect to collaborative edit history, a special priority is given to those occurrences supplied with a long duration and high frequency of contributions and involvement of learners with user profiles indicating high educational level and experience in current topic. The learner can freely adjust connectivity of concepts to display desired perspectives and the constantly updated view focuses to show local connectivity of concepts in respect to desired features of the conceptual network to be highlighted. To

optimize cognitive load, the learner can adjust the number and type of concepts and arcs shown simultaneously and stay informed about already visited parts of concept maps.

To ensure and cumulatively enhance quality, each concept map and learning path submitted to the database is collaboratively evaluated by other learners assigning an overall *quality rating* on five-point Likert scale and more detailed ratings for each concept and relationship separately. Each concept map and learning path can be also annotated with comments concerning their reliability and usefulness. A learner can also publish a request to others about creating or editing concept maps or learning paths about a desired topic. To facilitate identifying related earlier submissions and then to explore or refine them, a search function enables learners to find most matching occurrences for a given set of key words, considering title, user profile, concepts, relationships, annotations and ratings.

We have carried out *empirical experiment* to evaluate educational gain of the proposed method. We report here corrected results that somewhat differ from those results reported in publication [P5], our analysis is based on material gathered from 147 university students of *introductory Java programming course* who we asked to draw with our method *concept maps* representing their knowledge about learning topic “programming”. Among these 147 students there were 124 men and 23 women and average of age of students was 20.86 years (median 20 years). Although we present here the results in English, the experiment was carried out in Finnish but we present the results here in English. User interface of an prototype tool used in the experiment is shown in Appendix M.

After eliminating unclear responses and transforming all concepts to non-conjugated base forms, and considering only those concepts and relationships mentioned by at least two students, we identified 167 unique concepts and 167 unique conceptual relationships between them. A full listing of these unique concepts and unique relationships supplied with occurrences in concept maps is shown in Appendix M. Five most frequent concepts, number of students who mentioned the concepts shown in parenthesis, were programming (90), object (62), method (60), java (57) and class (49). Five most frequent relationships, number of students who mentioned the relationships shown in parenthesis, were object -> method (29), class -> object (27), programming -> programming language (27), programming language -> java (18) and programming -> language (17).

Table 8.1 shows how 147 students gradually introduced relationships to concept maps about programming. It appears that the most popular conceptual relationship that the students added as their first conceptual relationship to concept maps was programming -> language (mentioned by 11 students). The most popular conceptual relationship to be added as their second conceptual relationship was programming -> programming language (mentioned by 7 students). The most popular conceptual relationship to be added as their third conceptual relationship was object -> method (mentioned by 6 students).

To analyze pedagogical value of the method we compared evolution of drawn concept maps to an extensive *narrative from 28 lectures* of introductory Java programming course (Sahami 2010). We computed that this lecture narrative contained

6291 unique concepts that had altogether 101599 occurrences. We compared drawn concept maps to co-occurring words in 18142 unique sentences of the lecture narrative. The high-ranking concepts and high-ranking conceptual relationships in drawn concept maps well matched with the high-ranking concepts and highest-ranking co-occurring concept pairs in the pedagogical narrative. For example, ten *highest-ranking concepts* of concept maps and ten highest-ranking concepts of narrative had overlap of about 65 percent, and ten *highest-ranking relationships* of concept maps and ten highest-ranking co-occurring concept pairs of narrative had overlap of about 50 percent. Motivated by additional analysis, we introduce here corrected results about experimentally gathered data and thus results reported here somewhat differ from those results originally presented in publication [P5].

Table 8.1. Listings showing how 147 students gradually introduced conceptual relationships to concept maps that they drew about programming, these three listings show the most occurring relationships in first, second and third relationship each student has added (n=147). Only those relationships are shown that were mentioned by at least two students.

The most actively introduced conceptual relationships when the student added <u>the first</u> relationship to her concept map		The most actively introduced conceptual relationships when the student added <u>the second</u> relationship to her concept map		The most actively introduced conceptual relationships when the student added <u>the third</u> relationship to her concept map	
<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>	<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>	<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>
programming -> language	11	programming -> programming language	7	object -> method	6
class -> object	8	class -> object	6	language -> python	4
programming -> programming language	8	programming language -> java	5	programming language -> c	4
programming -> object	4	language -> java	4	class -> method	3
programming -> object-oriented programming	3	language -> c	3	class -> object	3
programming -> program	3	object -> method	3	language -> java	3
object -> method	2	variable -> object	3	programming language -> java	3
program -> class	2	class -> method	2	method -> object	2
programming -> java	2	code -> program	2	object -> list	2
programming -> python	2	java -> object	2	object -> variable	2
programming -> tool	2	object -> variable	2	programming -> c++	2
programming -> variable	2	package -> class	2	programming -> java	2
variable -> object	2	programmer -> programming	2	programming -> language	2
		programming -> logic	2	programming -> program	2
		programming -> object	2		

From Table 8.2 it can be seen that among ten highest-ranking concepts for lecture narrative concepts (when counting concepts thing and things as one) there seem to be six concepts specific for describing learning topic of programming including: class, program, method, object, value and array. On the other hand ten highest-ranking concepts for concept maps about programming, if we first exclude language-related vocabulary and concepts directly referring to concept of programming itself, include five concepts: object, method, class, program and variable. Thus when comparing these two sets of concepts (six concepts and five concepts) four of them are shared (i.e. class, method, object and program) thus resulting in matching overlap of about 65 percent. We

think that this result indicates that the proposed relatively self-guided method can assist learners to generate and process knowledge in a pedagogically rewarding way, even challenging the knowledge evolution process suggested by a professional teacher.

Table 8.2. Highest-ranking concepts in lecture narrative of introductory Java programming course (having at least 262 occurrences) available from Sahami (Sahami 2010) and concept maps about programming (having at least 8 occurrences) drawn by students (n=147). Conjugated forms of concepts of concept maps were transformed into base form but concepts of lecture narrative were kept in initial conjugated forms since reliable automated transformation seemed challenging and manual transformation laborious.

Highest-ranking concepts in lecture narrative of introductory Java programming course		Highest-ranking concepts in concept maps about programming	
<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>
thing	1007	programming	90
class	902	object	62
program	836	method	60
time	757	java	57
things	742	class	49
name	640	program	47
way	613	programming language	44
method	604	variable	41
object	585	python	31
value	558	c	29
array	511	programmer	25
string	485	language	24
sort	478	object-oriented programming	22
set	463	computer	21
number	435	user	21
stuff	395	compiler	20
people	387	c++	19
means	368	code	17
run	367	user interface	16
line	350	loop	13
call	349	debugger	12
use	343	eclipse	12
doing	342	problem	11
computer	342	algorithm	9
variable	338	conditional sentence	9
file	330	int	9
take	327	parameter	9
show	327	program code	9
java	325	ready program	9
point	313	starting method	9
code	291	tool	9
example	283	library	8
list	263	machine language	8
type	262	testing	8
world	258		
start	255		
bit	254		

When analyzing the *highest-ranking conceptual relationships* in concept maps about programming shown in Table 8.3 (based on Appendix M), and first excluding language-related vocabulary and concepts directly referring to concept of programming itself, we ended up observing those nine highest-ranking relationships marked with an asterisk (*) and one of those six relationships marked with a double asterisk (**) since these six relationships share the same ranking. In these ten relationships 5 concepts become mentioned anyway (object (6 occurrences), class (5 or 6 occurrences), method (3 or 4 occurrences), variable (3 or 4 occurrences), program (1 or 2 occurrences)) and additionally possibly one of three concepts become mentioned (code (0 or 1 occurrences), package (0 or 1 occurrences) and programmer (0 or 1 occurrences)).

Table 8.3. Comparison concerning conceptual relationships of concept maps about programming and co-occurring concepts of lecture narrative of introductory Java programming course available from Sahami (Sahami 2010). As explained in main text of Subchapter 8.2 in our further analysis we ended up observing those nine highest-ranking relationships marked with an asterisk (*) and one of those six relationships marked with a double asterisk (**) since these six relationships share the same ranking.

The highest-ranking conceptual relationships in concept maps about programming drawn by students (n=147) (only those relationships occurring at least 5 times shown here, more shown in Appendix M)		How many times each of 50 highest-ranking concepts of lecture narrative of introductory Java programming course co-occurs with any other word(s) of 50 highest-ranking concepts in a same phrase, and how many times each of these 50 concepts occurs irrespective of co-occurrences		
Conceptual relationship	Occurrences	Conceptual relationship	Co-occurrences	Occurrences (ranking)
* object -> method	29	thing	344	1007 (1)
* class -> object	27	things	240	742 (5)
programming -> programming language	27	way	230	613 (7)
programming language -> java	18	name	214	640 (6)
programming -> language	17	sort	214	478 (13)
* class -> method	14	method	203	604 (8)
java -> object	14	time	198	757 (4)
programming -> program	14	class	196	902 (2)
* object -> variable	12	program	194	836 (3)
language -> java	11	set	180	463 (14)
language -> c	10	object	165	585 (9)
* program -> class	10	show	165	327 (27.5s)
* object -> class	9	means	161	368 (18)
* variable -> object	9	call	160	349 (21)
java -> object-oriented programming	8	doing	160	342 (23.5s)
language -> python	8	value	158	558 (10)
programming language -> c	8	array	155	511 (11)
programming -> object	8	use	155	343 (22)
programming -> object-oriented programming	8	run	144	367 (19)
programming language -> python	7	stuff	130	395 (16)
* class -> variable	6	number	127	435 (15)
* method -> object	6	string	125	485 (12)
object-oriented programming -> java	6	take	125	327 (27.5s)
programming -> computer	6	inside	120	235 (43)
programming -> java	6	people	118	387 (17)
programming -> tool	6	bunch	115	222 (48)
c -> c++	5	variable	111	338 (25)
** code -> program	5	computer	107	342 (23.5s)
java -> class	5	type	105	262 (34)
** method -> class	5	bit	105	254 (37)
** method -> variable	5	start	103	255 (36)
** package -> class	5	code	94	291 (31)
** programmer -> program	5	line	92	350 (20)
programmer -> programming	5	java	92	325 (29)
programmer -> programming language	5	list	81	263 (33)
programming -> programmer	5	example	79	283 (32)
programming -> user interface	5	text	79	219 (50)
programming -> variable	5	point	77	313 (30)
** variable -> method	5	size	72	229 (45.5s)
		file	69	330 (26)
		integer	66	232 (44)
		move	63	246 (38)
		case	63	241 (41s)
		zero	61	245 (39)
		world	58	258 (35)
		box	55	220 (49)
		album	52	226 (47)
		times	51	229 (45.5s)
		loop	46	241 (41s)
		screen	37	241 (41s)

From lecture narrative we identified how many times each of 50 highest-ranking concepts co-occurs with any other concept(s) of 50 highest-ranking concepts in a same phrase. The number of these co-occurrences is shown in Table 8.3 for each of 50 highest-ranking concepts. In this listing it can be seen that among ten highest-ranking concepts for lecture narrative concepts (when counting concepts thing and things as one) there seems to be six concepts specific for describing learning topic of programming including: sort, method, class, program, set and object. Thus when comparing these two sets of concepts (5 or 6 actively used concepts in relationships of concept maps about programming and 6 actively used concepts in phrase-based co-occurrences of lecture narrative) four of them are shared (i.e. class, method, object and program) thus resulting in matching overlap of about 65 percent.

We analyzed the drawn concept maps in respect to the *learner's self-evaluation* about three characteristics based on responses given by students after drawing concept map in experiment: amount of earlier programming experience, difficulty of learning programming and the complexity of the concept map she had drawn, measured with five-point Likert scale (response alternatives are listed in Appendix M). Based on this analysis Table 8.4 shows distribution of rankings of concepts of concept maps about programming in respect to responses given by students and Table 8.5 shows distribution of rankings of conceptual relationships of concept maps about programming in respect to responses given by students. Here we took into account only such concepts and conceptual relationships that were mentioned by at least two students. We observed surprisingly coherent concept maps to be drawn irrespective of the responses given in self-evaluation. For example, for ten highest-ranking concepts as well as conceptual relationships there was overlap of about 50 percent between more experienced and less experienced learners, between learners considering learning more difficult and learners considering it less difficult, and between learners who drew more complex concept maps and learners who drew less complex concept maps.

We think that these results indicate that our proposed method can assist learners to generate and process knowledge in such a way that lets even challenged learners to reach same knowledge qualities in their concept maps as the less-challenged learners can.

Table 8.4. Distribution of rankings of concepts of concept maps about programming in respect to responses given by students, for concepts mentioned by at least two students.

How much you have experience about programming before participating introductory programming course?					
Very little or little (n=80+39=119)		Moderately (n=20)		Very much or much (n=1+7=8)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	71	programming	14	java	5
object	57	compiler	7	programming	5
method	55	programming language	7	language	4
java	46	java	6	c	3
class	45	program	6	program	3
program	38	programmer	6	php	2
variable	36	method	5	programmer	2
programming language	35	object	5	programming language	2
python	28	object-oriented programming	5	python	2
c	23	variable	4		
Is it easy for you at the moment to learn programming?					
Very easy or easy (n=10+42=52)		Moderate (n=85)		Very difficult or difficult (n=1+9=10)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	30	programming	55	object	5
java	21	object	41	programming	5
method	16	method	40	method	4
object	16	class	35	program	4
program	16	java	34	class	3
programming language	16	program	27	user	3
c	12	programming language	26	variable	3
object-oriented programming	12	variable	26	algorithm	2
variable	12	python	21	c	2
class	11	c	15	code	2
programmer	11			computer	2
				int	2
				java	2
				language	2
				object-oriented programming	2
				programmer	2
				programming language	2
Please give an estimate about how complex things your concept map is dealing with?					
Very simple or simple (n=32+83=115)		Moderate (n=26)		Very complex or complex (n=4+2=6)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	71	programming	15	programming	4
object	51	object	10	java	2
java	50	method	9	language	2
method	50	program	9	program	2
class	41	programming language	9	python	2
program	36	class	7		
programming language	35	programmer	7		
variable	34	variable	6		
python	26	compiler	5		
c	24	java	5		

Table 8.5. Distribution of rankings of conceptual relationships of concept maps about programming in respect to responses given by students, for conceptual relationships mentioned by at least two students.

How much you have experience about programming before participating introductory programming course?					
Very little or little (n=80+39=119)		Moderately (n=20)		Very much or much (n=1+7=8)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
class->object	25	programming->programming language	5	language->java	3
object->method	24	object->method	5	programming->programming language	2
programming->programming language	20	programming->language	3	language->c	2
class->method	14	programming language->java	3	programming->language	2
java->object	14	(many, shown in footnote) ¹⁸	2	programming language->java	2
programming->program	13				
programming language->java	13				
programming->language	12				
object->variable	10				
language->c	8				
language->java	8				
variable->object	8				
program->class	8				
object->class	8				
Is it easy for you at the moment to learn programming?					
Very easy or easy (n=10+42=52)		Moderate (n=85)		Very difficult or difficult (n=1+9=10)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
programming->programming language	12	class->object	19	object->method	3
object->method	9	object->method	17	class->object	2
class->object	6	programming->programming language	15	programming->language	2
programming->program	5	programming language->java	13	object-oriented programming->java	2
language->java	5	java->object	12	programmer->code	2
programming language->java	5	programming->language	11	programming->object-oriented programming	2
java->object-oriented programming	4	class->method	10		
class->method	4	object->variable	9		
language->c	4	programming->program	8		
programming->language	4	program->class	7		
variable->object	4				
object->class	4				
programming->variable	4				
Please give an estimate about how complex things your concept map is dealing with?					
Very simple or simple (n=32+83=115)		Moderate (n=26)		Very complex or complex (n=4+2=6)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
object->method	25	programming->programming language	6	programming->language	2
class->object	22	class->object	4		
programming->programming language	21	object->method	4		
programming language->java	16	object->variable	3		
programming->language	14	programmer->program	3		
java->object	13	programming language->object-oriented programming	3		
class->method	12	(many, shown in footnote) ¹⁹	2		
programming->program	11				
language->java	10				
object->variable	9				
language->c	9				

¹⁸ Two occurrences: class->method; class->variable; input->method; method->object; method->output; method->variable; package->class; program->bug; program->class; program->compiler; program->function; program->library; program->user; programmer->programming; programming->logic; programming->program; programming language->c; programming language->java; programming language->machine language.

¹⁹ Two occurrences: c->c++; class->object; class->variable; input->method; java->object-oriented programming; method->variable; method->output; object->variable; program->bug; program->class; program->compiler; program->function; program->library; programming language->c;

8.3. Findings and their relation to the entity of the dissertation

We do not know any previous similar proposal for a concept map based wiki. We aim to augment traditional wiki techniques for creating, editing and applying knowledge in learning based on a diverse database of collaborative contributions supplied with user profiles. Initial experiments indicate promising pedagogical value and various educational games can be incorporated based on browsing and editing concept maps which can be agglomerated to maturing entities and ontologies that get gradually refined and provide complementing alternative conceptualizations. We think that knowledge structures and user logs gathered with the method can be exploited in daily educational work for evaluating students' learning progress, modeling collaborative learning processes and identifying patterns of successful learning. The method could be easily augmented with components resembling those that have been developed for traditional wikis, data mining and clustering algorithms.

Publication [P5] presents a method for gathering individually created and edited concept maps as a collective resource for various educational purposes. This method can be seen as a repository for knowledge structures extending the idea of collaborative framework presented in publication [P1].

In a similar way, publication [P5] can be seen to extend the methods introduced in publications [P2], [P3] and [P4] to guide educational exploration.

The method of publication [P2] described how to explore great knowledge structures which rely on linked pieces of knowledge. Method of publication [P3] augments that by using various measures to highlight diverse alternative perspectives that are available for browsing in knowledge structures and method of publication [P4] exploits using these perspectives in parallel and with varied temporal versions to reach pedagogically meaningful coverage. The previous publications together offer a general approach for browsing wiki based knowledge entities that is described in the context of the hyperlink network of the Wikipedia. We found out that same kind of approach suits well to educational exploration with collaboratively built concept map collection as explained in publication [P5]. In addition, concept maps for the collection introduced in publication [P5] can be at least partly produced with the methods described in earlier publications concerning guidance for building concept maps. Already so far identified bidirectional supportive relatedness between methods introduced in previous publications and publication [P5] gives motivation for developing even further methodology for connecting linked pieces of knowledge and we thus decided to present a new method with publication [P6].

Chapter 9. Agglomerating pieces of knowledge built by community of learners with concept maps

In publication [P6] we proposed methodology for *agglomerating pieces of knowledge* created by a community of learners. We now here first explain basic idea and motivation about agglomerating pieces of knowledge built by a community of learners with *concept maps* and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P6]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P6].

The framework introduced in publication [P5] represented educational knowledge with collaboratively edited collection of concept maps and method of publication [P6] can be seen as an extension to recommend educationally fruitful routings to explore similar kind of conceptual network. Figure 9.1 illustrates the main idea of the method proposed in publication [P6].

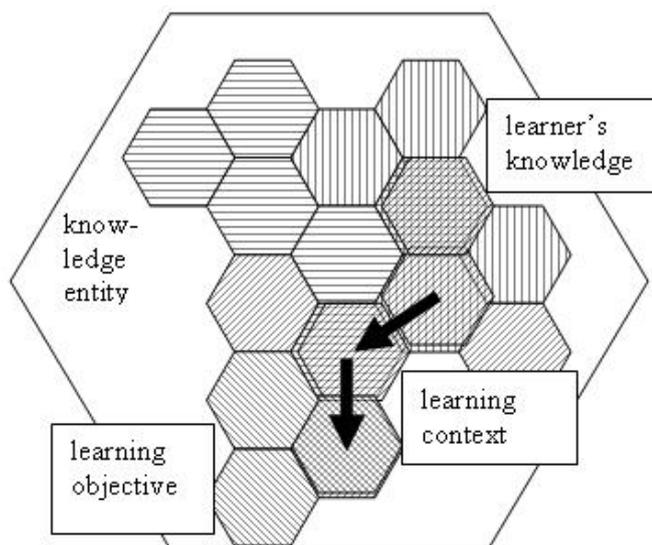


Figure 9.1. Main idea of the method proposed in publication [P6] for agglomerating pieces of knowledge built by community of learners with concept maps and how the learner can explore ranking-based routings connecting learning concept networks.

Similarly as in Figure 8.1, also in Figure 9.1 the linked hexagons together represented a collectively generated conceptual network. However now this network is not anymore a concept map collection as in publication [P5] but instead a collection of overlapping conceptual relationships representing the learner's knowledge, the learning objective and the learning context that are based on gathered text samples whose concepts are

linked based on corresponding hyperlinks of the Wikipedia. The method supports the learner to explore the shortest hyperlink chains leading from the learner's knowledge (represented with hexagons having vertical line pattern) to the learning objective (represented with hexagons having descending line pattern). The method recommends routes that can traverse either directly from the learner's knowledge to the learning objective or through intermediary parts based on contextual or collective conceptual network (each one represented with hexagons having unique line patterns), the latter case shown with two arrows in Figure 9.1.

9.1. Agglomerating knowledge in networks

The proposed method of publication [P6] aims to generate intuitive ways for connecting pieces of educational knowledge based on semantically motivated *routings in hyperlink network* of the Wikipedia.

Tetchueng et al. (Tetchueng et al. 2008) propose learning systems with generic context-aware scenarios to deal with problem-based learning based on a didactic model and community of practices. Lee and Kwon (Lee & Kwon 2008) suggest an expert system supporting collective decision making relying on fuzzy cognitive mapping with dynamic weighted graphs. Osmundson et al. (Osmundson et al. 1999) showed that collaborative concept mapping helps learning scientific and principled information and reaching inter-connectivity between systems of the learning topic. Suthers et al. (Suthers et al. 2009) showed that collaborative problem solving based on concept mapping outperformed threaded discussions and suggested a protocol for studying asynchronous collaboration. Gurlitt and Renkl (Gurlitt & Renkl 2010) represented how different concept mapping tasks lead to a variety of cognitive processes, learning outcomes and perceived self-efficacy. Chujo [Chujo 2004] measured vocabulary levels in educational texts with a high-frequency word list based on the British National Corpus and identified a diverse set of partially shared and constantly evolving vocabularies. Hilpert and Gries (Hilpert & Gries 2009) suggest methods for interpreting temporarily ordered stages of corpora and studying language acquisition. They argue that vocabularies and conceptual relations have different configurations for each individual, group, developmental stage and context.

Graph theoretical brain network analysis has gained promising attention and small-world topology has been observed in human brain networks under various structural and functional conditions (Wang et al. 2010). Goldstone et al. (Goldstone et al. 2008) argue that in dissemination of innovations in a social network, small-world networks are beneficial when solving a difficult problem. Auber et al. (Auber et al. 2003) suggest that relevant information on the network can be deduced from a hierarchical decomposition into small-world sub-networks and the hierarchy can be efficiently used to navigate the network. Zhao (Zhao 2009) demonstrated a documentation process enabling to construct and visualize small-world network models and to establish the paths within the models by searching the related web pages. Zaidi et al. (Zaidi et al. 2009) suggest a

clustering method to identify hidden community structures and to facilitate browsing Web pages in scale-free small-world network.

Due to previous results and since the Wikipedia holds scale-free small-world properties ((Zesch & Gurevych 2007); (Masucci et al. 2011)), we think that the Wikipedia's hyperlink network can inherently provide relatively optimal structure for exploring educational knowledge.

9.2. Finding learning paths with learning concept networks

Relying on the knowledge structure of the Wikipedia, in publication [P6] we propose a new computational method to support personalized adoption of knowledge by creating the closest mappings between *learning concept networks*. We think that for any topic it is possible to define a variety of alternative learning concept networks each one addressing a specific perspective and being based on a unique collection of concepts, called as a *key vocabulary*, and specific relationships determined between these concepts.

Some important features for collective intelligence systems are possible individual user actions, system state, as well as community and individual objectives (Lykourantzou et al. 2009). Motivated by previous results, we suggest generating learning concept networks for three complementing perspectives: the learner's knowledge, the learning objective and the learning context. *Learner's knowledge* refers to a personally flavored entity of knowledge and perspective about a certain learning topic acquired by the learner. *Learning objective* refers to a compact yet thorough entity of widely agreed knowledge describing a learning topic. *Learning context* refers to a diverse collection of everyday knowledge and collectively shared perspectives surrounding a learning topic induced by the members of the learner's community.

Motivated by convincing learning results based on *high-frequency word lists* (Masterson et al. 2010), in our method key vocabularies are identified by selecting a set of concepts having the highest frequencies in a representative text sample. A text sample for learning objective is gained by retrieving a Wikipedia article whose title matches with the topic. A text sample for learner's knowledge is gained by asking the learner to write a short improvised essay explaining her current conceptualization about the topic or the learner may just provide a list of few essential key concepts describing the topic, or draw a simple concept map representing key concepts and their relationships. A text sample for learning context is gained by collecting an extensive set of essays (or lists of key concepts or concept maps) from various learners in which they collectively describe their cumulative conceptualization about a variety of everyday topics. In our method, each learning concept network is built by connecting concepts of the key vocabulary based on the shortest hyperlink chains between corresponding Wikipedia articles.

We have implemented the proposed method in a prototype relying on a relational MySQL database storing learning concept networks in compact text format and a Java application enabling to visually edit and browse concept maps based on Java Database

Connectivity interface (JDBC API). We used *online database service “Six degrees of Wikipedia”* to make queries about the shortest hyperlink chains between any given two concepts in the English edition of Wikipedia, based on article collection dating from 3 March 2008 (Dolan 2011).

When finishing this dissertation it seems that the online database service “Six degrees of Wikipedia” (Dolan 2011) may not anymore return to be functional as it used to be but it needs to be emphasized that our results gained with that online service were needed especially as a proof of concept in preliminary experiments of prototyping. Thus we expect that our results should remain their value irrespective of functioning of that online service (please note that we have mentioned this claim already in publication [P6]) and could be successfully replicated and applied with alternative similar methods if needed and in fact in Subchapters 11.2–11.4. we report about further experiments that we have carried out which aim to cover similar tasks of finding the shortest path between a pair of Wikipedia articles (based on article collection dating from June-July 2013) as was provided by online database service (Dolan 2011).

Since longer hyperlink chains tended to reveal some interesting indirect relatedness but also to introduce ambiguousness, we decided to consider only chains containing one hyperlink or two hyperlinks with a requirement that the intermediate concept also belongs to key vocabulary. Based on occurrence distribution in collection of all the shortest hyperlink chains, our method creates two rankings: *concept ranking* for concepts belonging to key vocabulary and *hyperlink ranking* for hyperlinks existing between pairs of concepts belonging to key vocabulary.

The method builds a learning concept network based on representative sets of concepts and hyperlinks that have reached the highest rankings and introduces a *three-level pedagogic hierarchy* to indicate pedagogic value of concepts and hyperlinks. The method first adds the highest-ranking concepts and better half of them belong to the first level while the others to the second level. Then the method adds the highest-ranking hyperlinks and better half of them belong to the first level while the rest to the second level. These hyperlinks can connect already existing concepts or alternatively additional concepts need to be added which belong to the third level. Finally, the method aims to connect still separate segments of the network into one entity by gradually adding new hyperlinks and possibly new concepts based on the remaining ranking list of hyperlinks. In this last phase both concepts and hyperlinks belong to the third level.

By comparison, the method tries to find shared vocabularies, i.e. concepts that are shared by each pair of learning concept networks, called as *learner–context vocabulary*, *context–objective vocabulary* and *learner–objective vocabulary*. They enable to define a minimal collection of the shortest hyperlink chains that connect all concepts belonging to a pair of learning concept networks, called as *learner–context routing*, *context–objective routing* and *learner–objective routing*. Learning concept networks are illustrated to the learner as personalized adaptive concept maps, called as *learner’s knowledge map*, *learning context map* and *learning objective map*. To avoid excessive cognitive load, these concept maps are typically shown to the learner only partially step by step along the learning scenario. Our proposed method aims to support learning basically with two complementing modes that can be also mixed together: assisted

construction and assisted evaluation. In both modes, despite the actual direction of hyperlinked concepts each hyperlink can be traversed in both directions.

9.3. Implementing learning activities with learning concept networks

In *assisted construction mode*, the method recommends what hyperlinked concepts could be next added to learner's knowledge map to gradually approach concepts belonging to learning objective map. Two complementing approaches are available. In *focused approach*, the learner is recommended to traverse hyperlinks along learner-objective routing to reach concepts of learning objective map. In *contextualized approach*, the learner is first recommended to traverse hyperlinks along learner-context routing to reach learner-context vocabulary in learning context map. Next, the learner is recommended to traverse in learning context map the shortest hyperlink chains connecting learner-context vocabulary and context-objective vocabulary. Then the learner is recommended to traverse hyperlinks along context-objective routing to reach concepts of learning objective map. In both approaches, the learner is finally asked to traverse the shortest hyperlink chains connecting all concepts of learning objective map. Focused approach aims to emphasize the learner's personal perspective and specific conceptual details in acquisition of new knowledge whereas contextualized approach tries to emphasize collectively shared perspectives in her community and conceptual structures on a broader scale.

Based on the recommendations, the learner is expected to explore conceptual structures hyperlink by hyperlink and meanwhile to expand gradually the learner's knowledge map by adding new hyperlinked concepts to represent her knowledge acquisition process, resembling methods introduced in publications [P2]-[P4]. In each step, the method shows two updated ordered lists of the currently most recommended hyperlinks to traverse next for both focused and contextualized approach, sorted in decreasing order of significance. The orderings of the lists are generated to guide the learner to proceed in the parallel hyperlink chains of routings in an order similar to breadth-first graph search algorithm. Hyperlinks that diverge from routings are also recommended but with lower rankings. Beside the hyperlinked concept, each row in the list shows a condensed relation statement extracted from the text defining the hyperlink in corresponding Wikipedia article (verb and some adjacent words nearest to the hyperlink anchor in this article).

In *assisted evaluation mode*, the learner is provided with the learner's knowledge map but without recommendations based on routings concerning what hyperlinked concepts could be next added. Two alternative types of browsing can be used. In *targeted browsing*, the learner is provided with a list of all concepts belonging to learning objective map and she is asked to expand learner's knowledge map gradually until reaching these concepts. In *open browsing*, concepts belonging to learning objective map are not revealed to the learner and she is simply asked to expand learner's knowledge map gradually until she considers that it covers the most essential concepts

in the learning topic. Targeted browsing aims to emphasize learning towards predefined goals whereas open browsing tries to emphasize learning with learner-driven goal-setting. In both types of browsing, the learner is allowed to add only such a hyperlinked concept that there is a corresponding Wikipedia article directly hyperlinked from/to another Wikipedia article corresponding to a concept currently belonging to learner's knowledge map. The learner is asked to mark concepts that she considers to represent everyday knowledge or collectively shared perspectives with a label "contextualized" and concepts that she considers to represent more specific knowledge or personal perspectives with a label "focused".

When the learner has decided to finish, the method compares how much the gradually added hyperlinked concepts, both "contextualized" and "focused", correspond to exploring the routings based on the recommendations of the assisted construction mode with contextualized and focused approaches respectively. The amount of overlap between added hyperlinked concepts and the routings is used to measure the quality of the learner's learning efforts and is reported to the learner. Both in assisted construction mode and assisted evaluation mode, the learner is expected to encounter and become fruitfully exposed to conceptual structures that pedagogically relate her previous knowledge to new knowledge about the learning topic. If the learner is unfamiliar with a concept recommended by the method, she is provided with a definition by showing a Wikipedia article with a corresponding title. The process remains relatively self-guided in all steps and it typically ends when the learner self considers.

To evaluate the educational value of the proposed method we performed preliminary testing based on simple *learning scenarios* about children aiming to adopt basic vocabulary used in everyday life. The key vocabularies of learner's knowledge and learning objective consisted of the highest-ranking 10 percent of the nouns in text samples provided by the learner and the Wikipedia article respectively about selected topics. The key vocabulary of learning context consisted of 100 highest-ranking nouns used by English speaking children queried from Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) for combination of early educational levels denoted by "Rec/Prep/K" that we will refer to as school level Preparatory (<http://www.oxfordwordlist.com/pages/search.asp>). Appendix O shows the key vocabulary of learning context as well as one key vocabulary of learner's knowledge and one key vocabulary of learning objective in one of the learning scenarios concerning learning topic "child".

Based on three key vocabularies shown in Appendix O, Figure 9.2 (originally published as Figure 1 in publication [P6]) illustrates learning context map (a), learning objective map (b) and learner's knowledge map (c) in one of the learning scenarios concerning learning topic "child". Arc labels (i.e. relation statements) were omitted from the figure to preserve clarity. To indicate three-level pedagogic hierarchy for concepts, the first level has bold font, the second level normal font, the third level italics font and concepts added in the final connecting phase an asterisk (*). To indicate three-level pedagogic hierarchy for hyperlinks, the first level has bold arcs, the second level normal arcs and the third level dotted arcs. In the shown case, learner-objective vocabulary and learner-objective routing turn out to be empty and thus the focused

approach cannot be used but contextualized approach is still applicable. Learner-context vocabulary contains concepts Father, Game, School and Sibling, and context-objective vocabulary a concept Time. Between these concepts the shortest hyperlink chains in learning context map rely on the following hyperlink chains: Father<-Family->Sibling, Family<-Party->School, Family<-House<-Toy<->Game, Toy->Food->School, Party<-Holiday<->Day<->Time and Game<->Play(activity)<-Play(disambiguation)<-Party.

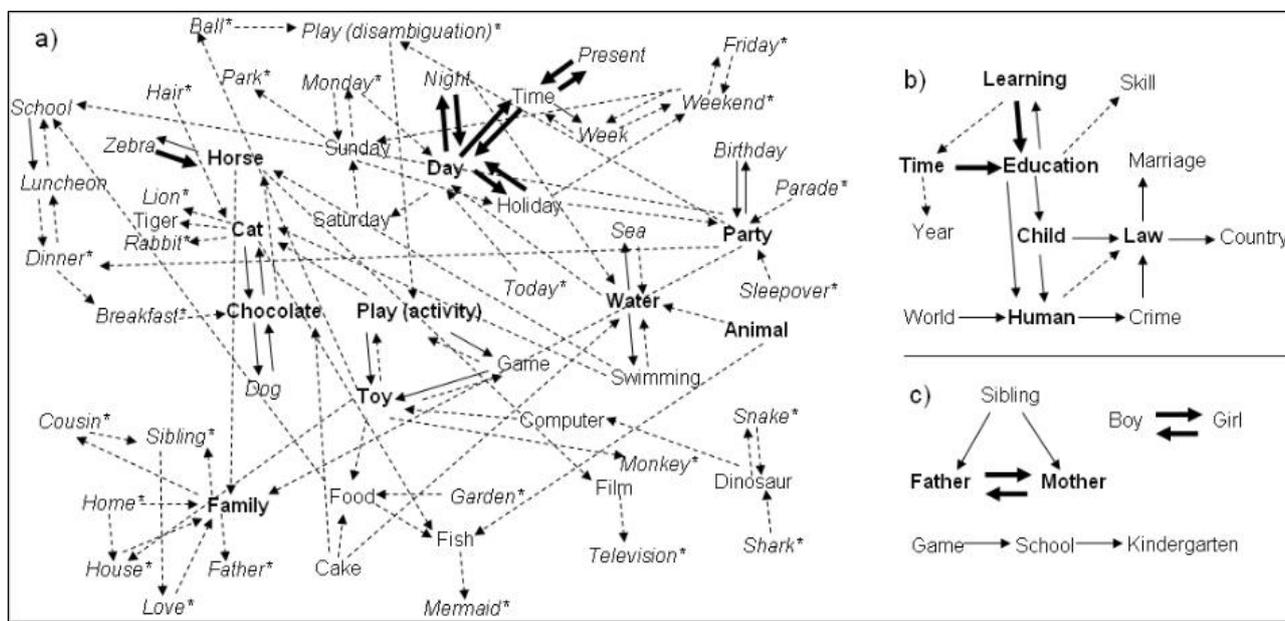


Figure 9.2. (originally published as Figure 1 in publication [P6]). Learning context map (a), learning objective map (b) and learner's knowledge map (c).

Figure 9.3 (originally published as Figure 2 in publication [P6]) shows in user interface how the learner, currently at concept Family, explores conceptual structures leading from learner's knowledge map to learning objective map, following hyperlink by hyperlink the recommendations given by the method. Please note that preferred traversing direction may go against the actual direction of hyperlink. In the shown case the learner is using contextualized approach. Just before arriving to current status the learner might have traversed hyperlinks Sibling<-Family and Father<-Family (written here in preferred traversing direction against the actual direction of hyperlinks and thus the learner would have in practice traversed from concept Sibling to concept Family and from concept Father to concept Family). The method shows sequentially lists of the currently most recommended hyperlinks to traverse next. In contextualized approach while currently at concept Family the learner can now select for example to traverse next hyperlink Family<-Party (in practice traversing from concept Family to concept Party). Therefore a chain of traversed hyperlinks leading from learner's knowledge map to learning objective map might include for example following hyperlinks (written here in preferred traversing direction that may go against the actual direction of hyperlinks): Sibling<-Family, Father<-Family, Family<-Party, Party<-Holiday, Holiday<->Day and Day<->Time. The learner is also recommended to explore hyperlinks that diverge from routings and which cross-link concepts of vocabularies. We think that even this small

sample gives convincing emphasis on some essential conceptual structures about learning topic “child” and indicates educationally valuable resource for adoption of new concepts and overall conceptualization of the learner.

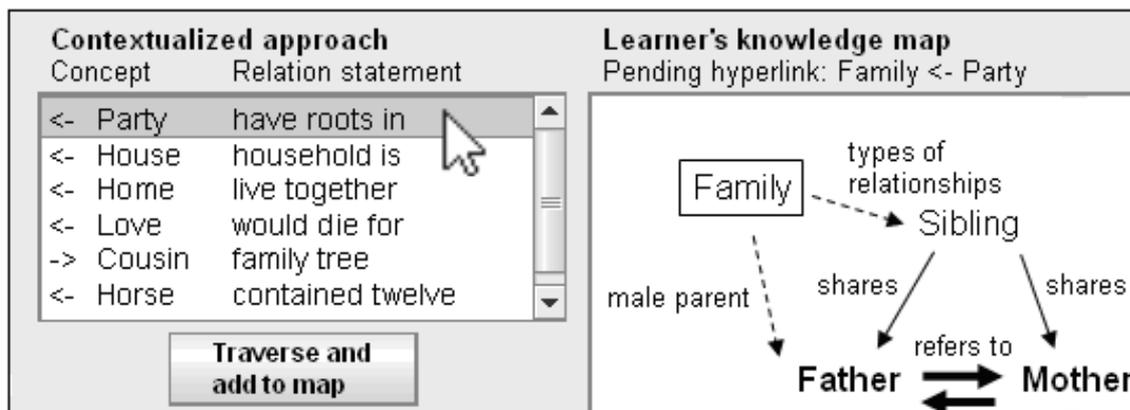


Figure 9.3. (originally published as Figure 2 in publication [P6]). User interface (an excerpt) of the prototype in assisted construction mode.

To verify the suggested pedagogic value of knowledge acquisition with the proposed method we gathered an extensive *collection of concept maps* drawn by 103 students describing their flow of association covering diverse pedagogic topics and containing 1827 conceptual relationships and compared them to corresponding *automated exploration patterns* in learning concept networks containing 1601 conceptual relationships generated with the proposed method. Here we mean with automated exploration pattern that the student is supplied with a computer-assisted navigation system that automatically retrieves and visualizes available hyperlinks to be traversed next from current concept but however student is expected to actively select the next hyperlink to traverse from provided set of alternative hyperlinks. Therefore we compared *traversed hyperlinks* in exploration paths in “hyperlink network of 55 concepts” (n=49) which we consider automated exploration patterns with *conceptual relationships in concept maps* drawn by students (n=103) which we consider non-automated exploration patterns. In this current analysis, the set of conceptual relationships in concept maps drawn by students is based on same sample that we introduced in Subchapter 3.9 (it is explained in Subchapter 3.9 how we gathered this sample).

In statistical comparison, we found positive correlation among the highest-ranking conceptual relationships between automated and non-automated exploration patterns in various topics with overlap ranging up to 60–70 percent, thus indicating that automated method can fruitfully guide the learner’s exploration along paths that are intuitively preferred in non-automated learning. With resembling positive results, we found convincing overlap even when comparing automated exploration patterns of younger learners to non-automated exploration patterns of older learners thus indicating that the method can enhance maturing of learning process. Similarly, the method seemed to enhance how individual conceptual relationships agglomerated and concept maps matured along the exploration. It thus seems that the method can support learning with

recommendations based on traversing hyperlink chains to form the closest mappings between all concepts of the learning concept networks.

Table 9.1 enables comparison of the highest-ranking core relationships²⁰ in concept maps drawn by students and the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (full listing is shown in Appendix N). Table 9.2 enables comparison of rankings of the highest-ranking core relationships of concept maps and the highest-ranking traversed hyperlinks that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N).

Table 9.1. Comparison of the highest-ranking core relationships in concept maps drawn by students (n=103) and the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), based on listings of Table 3.9 and Appendix K (full listing is show in Appendix N). Those relationships that exist in both listings are indicated with an asterisk (*). This table is limited to shown only those core relationships having at least 6 occurrences and those traversed hyperlinks having at least 13 occurrences, for full listing see Appendix N. The number of traversals for hyperlinks departing from Human (i.e. value 19) includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis (i.e. value 2) is shown the number of traversals when excluding those traversed hyperlinks departing from concept Human that were the student's first traversed hyperlink in exploration path.

<i>Concept maps drawn by the students (n=103)</i>			<i>Exploration paths in the Wikipedia (n=49)</i>		
<i>Core relationships (i.e. relationships between 102 core concepts extended with concept "brother" that are mentioned by at least two students in concept maps drawn by students) shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, thus each pair of concepts are shown in alphabetical order) (n=103)</i>	<i>Occurrences (at most one occurrence counted for each student)</i>	<i>Ranking</i>	<i>Traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>	<i>Occurrences (at most one occurrence counted for each student)</i>	<i>Ranking</i>
Family#Friendship	15	1	Happiness -> Emotion	29	1
* Birth#Death	13	2s	* Emotion -> Love	26	2
* Family#Love	13	2s	Joy -> Happiness	24	3s
Friendship#School	10	3	* Disease -> Death	24	3s
* Family#Home	9	4s	Happiness -> Joy	21	4
School#Work	9	4s	Human -> Diet_(nutrition)	19 (2)	5s
* Animal#Nature	8	5s	Emotion -> Experience	19	5s
* Friendship#Love	8	5s	Experience -> Emotion (only to roll back)	18	6
* Child#Family	7	6s	Organism -> Biology	17	7s
Death#Living	7	6s	Adolescence -> Education	17	7s
* Family#Father	7	6s	* Love -> Friendship	16	8
Family#Living	7	6s	Education -> Learning	14	9s
Joy#Sorrow	7	6s	Learning -> Education	14	9s
* Family#Mother	6	7s	Emotion -> Happiness	14	9s
* Father#Mother	6	7s	* Family -> Mother	13	10s
Food#Water	6	7s	Diet_(nutrition) -> Health	13	10s
Friendship#Hobby	6	7s	* Health -> Disease	13	10s
Money#Work	6	7s			

²⁰ Please note that a specific meaning for term "core relationship" has been defined in Subchapter 3.10.

In contrast with practice used often elsewhere in this publication, in Table 9.1, Table 9.2 and Appendix N if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is a ranking value that would have been used next if there was not need for sharing the position (i.e. we now avoid using an average of all ranking values that would have been used if there was not need for sharing the position and skipping corresponding number of ranking values). We decided to use all ranking values even in case of shared ranking so that our analysis about overlap of listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks could become more intuitive in the following text.

Figure 9.4 enables comparison of rankings of *highest-ranking core relationships of concept maps drawn by students* (34 relationships) and *highest-ranking traversed hyperlinks* in exploration paths of students (51 hyperlinks of which 17 are unidirectional and 34 have a hyperlink going also into opposite direction) that are shared by both listing of core relationships of concept maps and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N).

Based on Table 9.2 we compared listing of highest-ranking core relationships in concept maps drawn by the students (in column 1) and listing of highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (in column 4), this analysis was assisted by a third listing showing traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks (in column 8).

When considering traversed hyperlinks that have a ranking position as high as possible in both listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks based on their average (in column 8) it turned out that four hyperlinks with this kind of highest average ranking positions (Love->Friendship, Disease->Death, Family->Mother and Love->Family) covered four ranking levels of seven first ranking levels for core relationships (based on ranking levels shown in column 3) and four ranking levels of eight first ranking levels for traversed hyperlinks (based on ranking levels shown in column 6). Thus with this sample we concluded that there was an overlap of core relationships and traversed hyperlinks in the range 50–57 percent ($4/8=0.50$ and $4/7\approx 0.57$).

Similarly when considering eight hyperlinks with this kind of highest average ranking positions in column 8 (Love -> Friendship, Disease -> Death, Family -> Mother, Love -> Family, Emotion -> Love, Animal -> Nature, Health -> Disease, Love -> Happiness) these eight hyperlinks covered eight ranking levels of nine first ranking levels for core relationships (based on ranking levels shown in column 3) and eight ranking levels of ten first ranking levels for traversed hyperlinks (based on ranking levels shown in column 6). Thus with this sample we concluded that there was an overlap of core relationships and traversed hyperlinks in the range 80–89 percent ($8/10=0.80$ and $8/9\approx 0.89$).

Table 9.2 part 1 of 3 (starts here and continues on next page). Comparison of rankings of the highest-ranking core relationships of concept maps and the highest-ranking traversed hyperlinks that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). To enable comparison of core relationships and traversed hyperlinks each concept of core relationship is transformed to the closest matching entry of Wikipedia article. Based on Table 9.1 and Appendix N (Appendix N shows full listing) this table shows only those core relationships of concept maps drawn by students and traversed hyperlinks of the Wikipedia in exploration paths of students that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). In core relationships concepts are shown so that they are transformed to the closest matching entry of Wikipedia article. In columns 2 and 3 ranking values for core relationships are shown both among all core relationships and among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students. In columns 5 and 6 ranking values for traversed hyperlinks are shown both among all traversed hyperlinks and among only those traversed hyperlinks that are shared with core relationships. In column 7 ranking values are shown also for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing). In addition, column 9 shows a listing of traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks. This listing of column 9 aims to suggest a ranking of such relationships and hyperlinks that appear among the highest-ranking positions in both listing of core relationships and traversed hyperlinks, relying on average of ranking values for current hyperlink and corresponding relationship (from columns 3 and 6). Please note that listing of core relationships is shorter than listing of traversed hyperlinks.

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
Birth↔Death	2s	1s	Emotion -> Love	2	12s	1	Love -> Friendship	3
Family↔Love	2s	1s	Disease -> Death	3	14s	2	Disease -> Death	4.5s
Family↔Home	4	2	Love -> Friendship	8	20s	3	Family -> Mother	4.5s
Animal↔Nature	5s	3s	Family -> Mother	10s	21s	4s	Love -> Family	4.5s
Friendship↔Love	5s	3s	Health -> Disease	10s		4s	Emotion -> Love	5
Child↔Family	6s	4s	Love -> Happiness	11	18s	5	Animal -> Nature	6.5s
Family↔Father	6s	4s	Friendship -> Adolescence	12s	not existing	6s	Health -> Disease	6.5s
Family↔Mother	7s	5s	Love -> Emotion	12s	2	6s	Love -> Happiness	6.5s
Father↔Mother	7s	5s	Biology -> Nature	13s	not existing	7s	Child -> Family	7s
Nature↔Plant	8s	6s	Human -> Family	13s	not existing	7s	Family -> Child	7s
Plant↔Tree	8s	6s	Oxygen -> Water	13s	19s	7s	Human -> Family	7s
Death↔Disease	9s	7s	Death -> Disease	14s	3	8s	Biology -> Nature	7.5s
Family↔Human	9s	7s	Death -> War	14s	not existing	8s	Death -> Disease	7.5s
Human↔Love	9s	7s	Love -> Family	14s	not existing	8s	Friendship -> Adolescence	7.5s
Human↔Nature	9s	7s	Family -> Sibling	15s	20s	9s	Love -> Emotion	7.5s

Table 9.2 part 2 of 3 (started on previous page and continues here).

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
Animal↔Human	10s	8s	Plant -> Tree	15s	not existing	9s	Nature -> Animal	7.5s
Biology↔Nature	10s	8s	Sea -> Water	15s	15s	9s	Plant -> Tree	7.5s
Death↔Human	10s	8s	Water -> Sea	15s	15s	9s	Birth -> Death	8s
Death↔Old_age	10s	8s	Animal -> Human	16s	21s	10s	Death -> War	8s
Death↔War	10s	8s	Animal -> Nature	16s	18s	10s	Family -> Father	8s
Education↔School	10s	8s	Child -> Family	16s	16s	10s	Home -> Family	8s
Food↔Health	10s	8s	Death -> Human	16s	not existing	10s	Oxygen -> Water	8s
Happiness↔Love	10s	8s	Education -> School	16s	16s	10s	Plant -> Nature	8s
Home↔House	10s	8s	Family -> Child	16s	16s	10s	Father -> Family	8.5s
Nature↔Sun	10s	8s	Mother -> Love	16s	not existing	10s	Friendship -> Love	8.5s
Adolescence↔Friendship	11s	9s	Plant -> Nature	16s	19s	10s	Animal -> Human	9s
Disease↔Health	11s	9s	School -> Education	16s	16s	10s	Death -> Human	9s
Emotion↔Love	11s	9s	Teacher -> School	17	18s	11	Education -> School	9s
Family↔Sibling	11s	9s	Family -> Father	18s	19s	12s	Family -> Sibling	9s
Leisure↔Television	11s	9s	Happiness -> Love	18s	11	12s	School -> Education	9s
Love↔Mother	11s	9s	Nature -> Animal	18s	16s	12s	Sea -> Water	9s
Oxygen↔Water	11s	9s	Nature -> Human	18s	not existing	12s	Water -> Sea	9s
School↔Teacher	11s	9s	School -> Teacher	18s	17	12s	Father -> Mother	9.5s
Sea↔Water	11s	9s	Father -> Family	19s	18s	13s	Mother -> Father	9.5s
			Human -> Love	19s	not existing	13s	Mother -> Love	9.5s

Table 9.2 part 3 of 3 (started two pages earlier and continues here).

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
			Nature -> Plant	19s	16s	13s	Nature -> Human	9.5s
			Nature -> Sun	19s	not existing	13s	Nature -> Plant	9.5s
			Old_age -> Death	19s	not existing	13s	Happiness -> Love	10s
			Water -> Oxygen	19s	13s	13s	Human -> Love	10s
			Father -> Mother	20s	20s	14s	Mother -> Family	10s
			Friendship -> Love	20s	8	14s	Teacher -> School	10s
			Home -> Family	20s	not existing	14s	Nature -> Sun	10.5s
			House -> Home	20s	not existing	14s	Old_age -> Death	10.5s
			Mother -> Father	20s	20s	14s	School -> Teacher	10.5s
			Sibling -> Family	20s	15s	14s	House -> Home	11s
			Birth -> Death	21s	not existing	15s	Water -> Oxygen	11s
			Health -> Food	21s	not existing	15s	Health -> Food	11.5s
			Human -> Animal	21s	16s	15s	Human -> Animal	11.5s
			Leisure -> Television	21s	21s	15s	Sibling -> Family	11.5s
			Mother -> Family	21s	10s	15s	Leisure -> Television	12s
			Television -> Leisure (only to roll back)	21s	21s	15s	Television -> Leisure (only to roll back)	12s

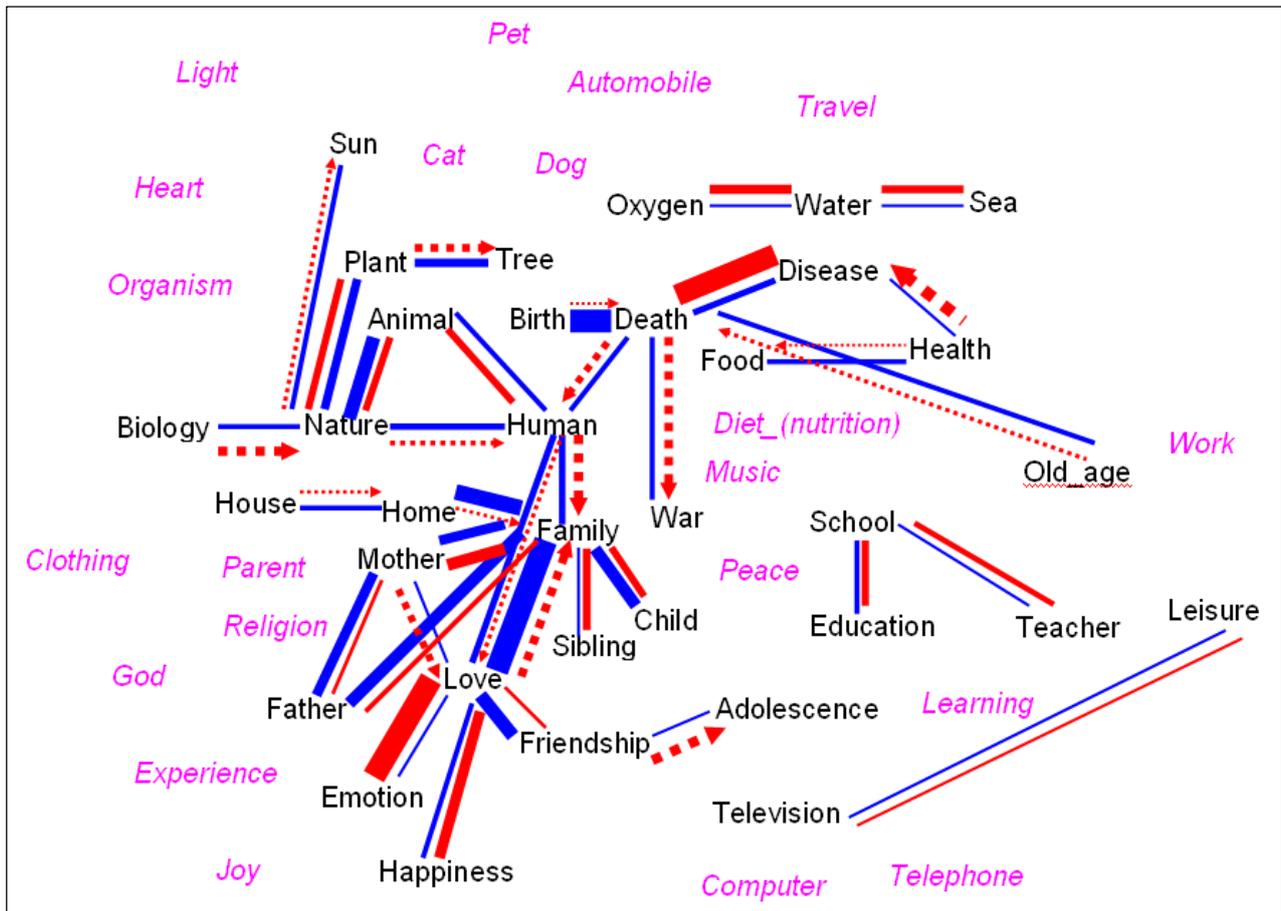


Figure 9.4. Based on Table 9.2 this figure shows only those core relationships of concept maps drawn by students ($n=103$) and traversed hyperlinks of the Wikipedia in exploration paths of students ($n=49$) that are shared by both listing of core relationships of concept maps and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). Figure contains all 55 concepts that were available for exploration paths of students and concepts written in pink color do not belong to those core relationships of concept maps and traversed hyperlinks that are shared by both listings (each concept is transformed to the closest matching entry of Wikipedia article). Core relationships of concept maps are shown with blue lines and traversed hyperlinks with red lines. Greater width of line indicates higher position in ranking among those core relationships of concept maps and traversed hyperlinks that are shared by both listings, and the range of line widths is normalized for both listings to enable direct comparability. If there is a traversed hyperlink in both directions between two concepts the connection is supplied with a solid line and the higher one of two available line widths is shown. If there is a traversed hyperlink in only in one direction between two concepts the connection is supplied with a dotted line that indicates direction with an arrow.

9.4. Findings and their relation to the entity of the dissertation

Consensus is missing for a general learning theory and many pedagogic theories are hard to implement computationally. Despite theoretic advances, there is a lack of educational tools letting the learner to construct interactively her learning path in the light of expressive sequential model, relying on for example strategic planning, game theory or stochastic network models. To address this, we suggest one possible generalizable method to support various personalized and contextualized learning tasks and pedagogic games, currently offering guidance for complementing learning modes of assisted construction and assisted evaluation with two variants. The method also enables

finding shared understanding with peers or teacher. Our method can be seen as an effort to agglomerate and synthesize parallel emerging ontologies that represent complementing perspectives of educational knowledge. We do not know any similar previous proposal.

The method of publication [P6] has been designed to address the challenge of finding the shortest path to connect pieces of educational knowledge. The method extends the ideas of previous publications. Publication [P1] defined a framework for collaborative building of concept maps representing shared knowledge structure. To extend that method, in publication [P6] we propose method allowing to identify the shortest paths to traverse in shared knowledge structure. Publication [P2] proposed a method recommending paths for exploration in the hyperlink network of the Wikipedia and thus can be seen to establish the underlying general principles to generate knowledge structures that are used in publication [P6]. Publication [P3] proposed using Wikipedia article statistics to find alternative exploration paths addressing various perspectives for browsing in Wikipedia and publication [P4] proposed exploring various parallel paths and using temporal versions to cover educationally fruitful knowledge. Extending those ideas of offering recommendation for pedagogically meaningful exploration in knowledge structures, the method of publication [P6] aims to find ways to connect individually created pieces of knowledge represented with concept maps. The publication [P5] presented idea of collective gathering of knowledge in form of concept maps and this collective approach can be augmented with the method of the publication [P6] to identify and exploit linking between pieces of knowledge.

PART V. Forming new educational activities based on vocabularies, conceptual networks and spaced learning

Chapter 10. Potential and constraints of new educational activities based on conceptual networks

In publications [P1-P6] we have proposed computational methods aiming to support a learner in adoption of knowledge and due to promising experimental results gained for those methods we think that it is important to still more relate our work to fundamental characteristics emerging in any typical learning situation. Thus we want to introduce a brief review about some fundamental characteristics that have been identified in previous research concerning *human learning process* and *representation of knowledge* and that according to us can be seen to offer both useful potential and challenging constraints for development of new educational activities based on conceptual networks especially in respect to computer-assisted education.

10.1. Challenge of verifying effectiveness of new learning methods

In educational research the effect that an intervention, for example a new more inspiring teaching method, has on learning achievements of students has been often measured with effect size. *Effect size* is often defined as a difference between the mean outcome for the intervention group and mean outcome for the control group, divided by pooled sample standard deviation. Alternatively, the effect size is a difference between the mean outcome in the end of intervention and mean outcome in the beginning of intervention, divided by pooled sample standard deviation. These are said to be two major formulas for calculating effect sizes (Hattie 2009). With this kind of definitions, the effect size is a measure expressing how many standard deviations fit between the mean of intervention group and the mean of control group, or correspondingly between the mean in the end of intervention and the mean in the beginning of intervention. Standard deviations are often different when measured on student level, class level, school level or national level making comparisons challenging. Bloom et al. (Bloom et al. 2008) mention that a *national standard deviation* is generally larger than standard deviation for study samples and that *student-level standard deviations* are typically several times the size of *school-level standard deviations* and furthermore that most studies use student-level standard deviations.

Effect size of 1.0 can be seen to indicate increase of one standard deviation on improving school achievement, corresponding to advancing student's achievement by 2–3 years, improving the learning rate by 50 percent or having a correlation of 0.50 between intervention method and achievement (Hattie 2009). Bloom et al. (Bloom et al.

2008) mention based on earlier research a widely cited benchmark that an intervention should have an effect size of 0.25 to be *educationally significant* (Tallmadge 1977) and that from 186 meta-analysis covering 6700 studies of educational, psychological and behavioral interventions it was found that bottom third of the distribution of effect sizes ranged between 0.00–0.32 standard deviation, middle third between 0.33–0.55 standard deviation and top third between 0.56–1.20 standard deviation (Lipsey 1990).

Based on 815 meta-analyses, covering 52637 educational studies with millions of students and 146142 effect sizes, Hattie (Hattie 2009) found that 95 percent of effect sizes were above zero, thus seeming to explain why almost any action has at least a mild positive effect on achievement, and that the *average of effect sizes* was 0.40 which he suggests to be used as a benchmark between effects that need more consideration and effects that are worth having. Hattie claims, motivated by his own New Zealand studies and results of Johnson and Zwick (Johnson & Zwick 1990), that teachers can accomplish on average an effect size of 0.20–0.40 on the student's school achievement per year. He considers effects sizes in range 0–0.15 to correspond developmental effects that can be achieved even without schooling, effect sizes in range 0.15–0.40 to correspond effects from a teacher in a typical year of schooling and effect sizes above 0.40 to correspond effects of influences that can be expected to have the greatest impact on the student achievement outcomes.

According to Hattie's synthesis of 815 meta-analyses (Hattie 2009), *six main categories of influences* (contributors) to learning and their average effect sizes, in parenthesis, are: teacher (0.49), curricula (0.45), teaching (0.42), student (0.40), home (0.31), and school (0.23). Hattie identified 138 different influences to learning belonging to these six categories and Table 10.1 shows forty influences having the highest-ranking effect sizes among these 138 influences in descending order of effect size. Table 10.2 shows all those influences to learning that belonging to category of "teaching" and have effect size of at least 0.40 according to Hattie. Just below threshold 0.40 are teaching influences concerning time on task (0.38), computer-assisted instruction (0.37) and adjunct aids (0.37).

When extending previous synthesis to cover 931 meta-analyses Hattie (Hattie 2012) found that the overall ranking of influences to learning based on effect size changed relatively little. Now six main categories of influences to learning and their average effect sizes are: teacher (0.47), curricula (0.45), teaching (0.43), student (0.39), home (0.31), and school (0.23). In respect to forty highest-ranking effect sizes shown in Table 10.1, now four old influences dropped out, including home environment (0.52), socio-economic status (0.52), professional development (0.51) and goals (0.50), and four new influences entered, including response to intervention (1.07), teacher credibility (0.90), classroom discussion (0.80) and student-centered teaching (0.54). In respect to teaching influences having effect size of at least 0.40 shown in Table 10.2, now two old influences dropped out, including social skills programs (0.39) and matching style of learning (0.17).

Table 10.1. Forty influences to learning that have the highest-ranking effect sizes according to Hattie's meta-analysis (Hattie 2009) concerning 138 influences, each influence shown with rank, category and effect size in descending order of rank.

Rank	Category	Influence	Effect size
1	student	self-report grades	1.44
2	student	Piagetian programs	1.28
3	teaching	providing formative evaluation	0.90
4	teacher	micro teaching	0.88
5	school	acceleration	0.88
6	school	classroom behavioral	0.80
7	teaching	comprehensive interventions for learning disabled students	0.77
8	teacher	teacher clarity	0.75
9	teaching	reciprocal teaching	0.74
10	teaching	feedback	0.73
11	teacher	teacher-student relationships	0.72
12	teaching	spaced vs. mass practice	0.71
13	teaching	meta-cognitive strategies	0.69
14	student	prior achievement	0.67
15	curricula	vocabulary programs	0.67
16	curricula	repeated reading programs	0.67
17	curricula	creativity programs	0.65
18	teaching	self-verbalization/self-questioning	0.64
19	teacher	professional development	0.62
20	teaching	problem-solving teaching	0.61
21	teacher	not labeling students	0.61
22	curricula	phonics instruction	0.60
23	teaching	teaching strategies	0.60
24	teaching	cooperative vs. individualistic learning	0.59
25	teaching	study skills	0.59
26	teaching	direct instruction	0.59
27	curricula	tactile stimulation programs	0.58
28	curricula	comprehension programs	0.58
29	teaching	mastery learning	0.58
30	teaching	worked examples	0.57
31	home	home environment	0.57
32	home	socioeconomic status	0.57
33	teaching	concept mapping	0.57
34	teaching	goals	0.56
35	curricula	visual-perception programs	0.55
36	teaching	peer tutoring	0.55
37	teaching	cooperative vs. competitive learning	0.54
38	student	pre-term birth weight	0.54
39	school	classroom cohesion	0.53
40	teaching	Keller's Personalized System of Instruction	0.53

Based on meta-analysis covering more than 100 studies, Marzano et al. (Marzano et al. 2001) listed *nine categories of instructional strategies* that have a strong influence on student achievement and gave estimates for the average effect size of each of these strategies: identifying similarities and differences (1.61), summarizing and note taking (1.00), reinforcing effort and providing recognition (0.80), homework and practice (0.77), nonlinguistic representations (0.75), cooperative learning (0.73), setting objectives and providing feedback (0.61), generating and testing hypotheses (0.61), and questions, cues and advance organizers (0.59).

Table 10.2. All those influences to learning that belong to category of teaching and have effect size of at least 0.40 according to Hattie’s meta-analysis (Hattie 2009), shown in descending order of effect size and with value of ranking among all 138 influences.

Rank	Category	Influence	Effect size
3	teaching	providing formative evaluation	0.90
7	teaching	comprehensive interventions for learning disabled students	0.77
9	teaching	reciprocal teaching	0.74
10	teaching	feedback	0.73
12	teaching	spaced vs. mass practice	0.71
13	teaching	meta-cognitive strategies	0.69
18	teaching	self-verbalization/self-questioning	0.64
20	teaching	problem-solving teaching	0.61
23	teaching	teaching strategies	0.60
24	teaching	cooperative vs. individualistic learning	0.59
25	teaching	study skills	0.59
26	teaching	direct instruction	0.59
29	teaching	mastery learning	0.58
30	teaching	worked examples	0.57
33	teaching	concept mapping	0.57
34	teaching	goals	0.56
36	teaching	peer tutoring	0.55
37	teaching	cooperative vs. competitive learning	0.54
40	teaching	Keller’s Personalized System of Instruction	0.53
44	teaching	interactive video methods	0.52
53	teaching	questioning	0.46
61	teaching	behavioral organizers / adjunct questions	0.41
62	teaching	matching style of learning	0.41
63	teaching	cooperative learning	0.41

In teaching word meanings, Eeds and Cockrum (Eeds & Cockrum 1985) compared three instructional methods based on teaching words by helping students to expand existing conceptual network, having students to pair new words with dictionary definitions and having students to read words in meaningful context of junior novel, and they found that the first method was significantly more effective than the other two methods. When compared to a traditional learning method with listing and studying definitions, Carr and Mazur-Stewart (Carr & Mazur-Stewart 1988) managed to significantly improve vocabulary comprehension and retention of terms with a method relying on a graphic organizer to relate text information, personal clues to associate terms with background knowledge and self-monitoring checklist to assess understanding.

We have experimentally gathered data covering the educational processes when the learner explores and builds linked knowledge structures. To reliably make comparative evaluation, we have carried out observation in conceptual network corresponding to a small but specifically selected subset of the hyperlink network of Wikipedia. With this subset we hope to have enough overlap to cover activities of various learners and to successfully compare the structural characteristics emerging in the conceptualization of both the individual learner and mutual agreement about well-defined basic knowledge done by collective community building the Wikipedia. We empirically observed how learners proceed and form conceptual chaining in the conceptual network of “hyperlink

network of 55 concepts” (characteristics of “hyperlink network of 55 concepts” are described in Subchapter 5.3).

We have carried out with 73 students having ages in range 16–20 years an experiment that tries to enable to analyze the *process of exploration tasks* in hyperlink network of the Wikipedia and to give verification to *suggested educational benefits* gained with these exploration tasks. This exploration experiment and its results have been discussed in publication [P7] but based on further experiments after publishing publication [P7] we now present here partially different, corrected results. We compared two learning cases by asking an experiment group and a control group to perform an exploration task. Although we present here the results in English, the exploration task was carried out in Finnish based on Finnish translations of all 212 hyperlinks shown in Appendix J supplied with a relation statement for each hyperlink.

Each member of the *experiment group* (n=49) was allowed to browse freely following their intuition in the conceptual network for twenty steps. This exploration task was carried in “hyperlink network of 55 concepts” starting from concept Human (all 212 hyperlinks of “hyperlink network of 55 concepts” supplied with their relation statements are listed in Appendix J). At each step a few alternative hyperlinked concepts to be traversed next were shown to the student and the student actively selected which of these hyperlinked concepts to traverse next. Each of hyperlinked concepts were highlighted and accompanied with sentence related to corresponding hyperlink and each of these hyperlinks could be traversed only once (thus each traversed hyperlink disappears from being shown if exploration would later arrive back to start concept of traversed hyperlink). The student was given an instruction to read carefully all sentences in given list and to select with mouse the sentence whose emphasized word (ie. hyperlinked concept) is most naturally connected to current concept shown above the list. Table 5.10 illustrates how during exploration task the student performs consecutive steps of exploration in “hyperlink network of 55 concepts”, a full listing of hyperlinks is shown in Appendix J.

In contrast with experiment group, each member of the *control group* (n=24) on the other hand had to proceed a predefined fixed series of twenty text pages, each one of them providing same kind of sentences with highlighted hyperlinked concepts as for the experiment group but without continuity between these pages and without possibility to select a hyperlink to proceed next while keeping continuity between pieces of knowledge (the predefined fixed series of twenty text pages the students had to proceed is listed in Appendix W). Each of twenty pages represented a concept so that all hyperlinked concepts on this page corresponded to hyperlinks going from concept represented by this page to all those hyperlinked concepts and thus all hyperlinked concepts on same page had a shared start concept. However when proceeding to next page the concept represented by the next page was not any of those hyperlinked concepts of previous page and thus continuity between consecutive pages was minimized on purpose. The student was given an instruction to read carefully all sentences and emphasized words (ie. hyperlinked concepts) in a given list and then to press button Next with mouse to get a next list to be read.

After performing exploration task, both members of experiment group and members of control group were asked to recall and write all the highlighted hyperlinked concepts that had been shown to them during exploration task and duration of two minutes was given for this recall task. It needs to be noted that the participants were informed about the recalling task only after the exploration task had been already performed.

To identify how the suggested benefits of proposed method to support learning is related to characteristics of the students we asked after exploration task and subsequent recall task each student to report her gender and age and with four responses to estimate usefulness of the method when compared to traditional learning from a book, her interest in using the method for learning, how easy it is for her to adopt knowledge through reading and how successfully she performs at school (see Table 10.3, Table 10.4 and Table 10.5). The four last mentioned questions were replied by selecting a most suitable answer from a scale of five given alternatives. When reporting the results we have grouped some small statistical response groups with an aim to offer a better overall representation about the distribution of responses. Full listing of background characteristics of members of experiment group and control group as well as user interfaces of prototype tools used in experiment are shown in Appendix W.

Our aim was to form experiment group and control group so that they share approximately same background characteristics but it appears in Table 10.4 and Table 10.5 that in control group the distributions of adoption ability and school performance are possibly positioned at a bit lower level than in experiment group. In addition it should be noted that these estimates about adoption ability and school performance are self-reported by students and thus for example self-critical students may have underestimated their skills. Furthermore our aim was to enable such exploration tasks that are as matching as possible for experiment group and control group but since both groups participated our experiment at the same time it was not possible to get exactly matching exposure of concepts and thus we try to eliminate unnecessary bias in following analysis so that we consider only part of conceptual exposure of control group.

Table 10.3. The number, age and gender distribution of students in experiment group and control group.

Value	Experiment group (n=49)			Control group (n=24)		
	Male and female	Male	Female	Male and female	Male	Female
Number of students	49 (100 %)	18 (37 %)	31 (63 %)	24 (100 %)	12 (50 %)	12 (50 %)
Average of ages (years)	17.39	17.33	17.42	17.52	17.45	17.58
Variance of ages	0.74	0.71	0.78	1.35	1.27	1.54

Table 10.4. Responses to question “How easy it is for you to adopt new knowledge through reading?”.

Opinion	Experiment group (n=49)				Control group (n=24)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Very easy	6 %	3	1	2	4 %	1	1	0
Easy	43 %	21	7	14	25 %	6	2	4
Moderate	37 %	18	7	11	63 %	15	8	7
Difficult	10 %	5	3	2	8 %	2	1	1
Very difficult	4 %	2	0	2	0 %	0	0	0

Table 10.5. Responses to question “In your opinion, how successfully do you perform at school?”

Opinion	Experiment group (n=49)				Control group (n=24)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Excellently	10 %	5	3	2	4 %	1	0	1
Well	37 %	18	1	17	38 %	9	4	5
Satisfactorily	45 %	22	13	9	58 %	14	8	6
Fairly	8 %	4	1	3	0 %	0	0	0
Faintly	0 %	0	0	0	0 %	0	0	0

When observing exploration tasks we give emphasis on shown concepts and selected concepts. In following analysis with term *shown concepts* we refer to each of those highlighted hyperlinked concepts that become shown to the student during exploration task even if the student does not actively select to traverse to this hyperlinked concept (i.e. not necessarily actively selected but shown concepts), and with term *selected concepts* we refer to each of those highlighted hyperlinked concepts that the student actively selects to traverse during exploration task.

During exploration task of experiment group (n=49) on average 34.16 unique concepts were shown to each student and after the experiment student could recall on average 11.33 unique concepts (about 33.2 percent) of them, and on average 13.80 unique concepts were selected by each student and after the experiment student could recall on average 8.94 unique concepts (about 64.8 percent) of them. When considering repeated exposure of some concepts for experiment group on average 101.51 concepts were shown to each student meaning on average 2.97 occurrences of each unique concept. Appendix Y lists for each member of experiment group concepts actively selected by student during exploration task and recalled concepts after exploration task in respect to shown concepts and selected concepts.

During exploration task of control group (n=24) originally 42 unique concepts were shown to each student and when considering repeated exposure of some concepts for control group originally on average 148 concepts were shown to each student meaning originally on average 3.52 occurrences of each unique concept. To make conceptual exposure of experiment group and control group more matching to enable more reliable comparison about process of exploration tasks and suggested educational benefits gained with these exploration tasks we decided in following analysis to consider for control group only conceptual exposure concerning 34 most occurring concepts in exploration tasks of control group (when excluding eight concepts there were concepts having shared number of occurrences and here excluded concepts were selected in decreasing alphabetic order)²¹. Thus following analysis relies on such observation that

²¹ When we decided in the following analysis to consider for control group only conceptual exposure concerning 34 most occurring concepts in exploration tasks of control group the original set of 42 concepts with occurrences in parenthesis were: Biology (10), Oxygen (9), Human (8), Organism (8), Adolescence (7), Family (7), Leisure (6), Sibling (6), Animal (5), Child (5), Plant (5), Diet_(nutrition) (4), Old_age (4), Sun (4), War (4), Water (4), Disease (3), Emotion (3), Happiness (3), Heart (3), Religion (3), Clothing (2), Education (2), Father (2), God (2), Health (2), House (2), Learning (2), Light (2), Love (2), Mother (2), Music (2), Parent (2), School (2), Sea (2), Teacher (2), Tree (2), Automobile (1), Death (1), Friendship (1), Nature (1) and Travel (1). In the following analysis to consider for control group only conceptual exposure concerning 34 concepts we excluded these eight concepts: Sea, Teacher, Tree,

during exploration task of control group (24 persons) 34 unique concepts were shown to each student and after the experiment student could recall on average 11.21 unique concepts (about 33.0 percent) of them. When considering repeated exposure of some concepts for control group on average 137 concepts were shown to each student meaning on average 4.03 occurrences of each unique concept. Appendix Y lists for each member of control group recalled concepts after exploration task in respect to original set of 42 shown concepts and final limited set of 34 shown concepts.

We estimated the effect size in favor of *shown hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student was exposed to in experimental group and control group divided by square root of pooled variance (see Table 10.6). For the effect size in favor of experiment group in contrast with control group we got an estimate value of about 0.02 which indicates such effects that based on previous research of Hattie (Hattie 2009) while belonging to effect size range of 0–0.15 correspond to developmental effects that can be achieved even without schooling. Although this limited difference in effects of experiment group and control group seems at first to indicate no specific reason to contrast learning methods of experiment group and control group we think that this limited difference indeed enables us to verify that the learning methods of both experiment group and control group have about shared recall rate in respect to many hyperlinked concept that are shown relatively passively to the student during reading.

We next estimated the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in experiment group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student actively selects to traverse in experiment group and the hyperlinked concepts shown to her during her traversal of exploration path in experiment group divided by square root of pooled variance (see Table 10.7). For the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in experiment group we got an estimate value of about 1.38 which indicates such effects that based on previous research of Hattie (Hattie 2009) while belonging to effect size values above 0.40 correspond to effects of influences that can be expected to have the greatest impact on the student achievement outcomes. In addition, gained effect size 1.38 is much higher than the average effect sizes of six main categories of influences (contributors) to learning according to Hattie's synthesis of 815 meta-analyses that are in range 0.23–0.49 (Hattie 2009) or according to Hattie's synthesis of 931 meta-analyses in range 0.23–0.47 (Hattie 2012) as we have just mentioned above.

When comparing our gained effect size of 1.38 to the highest-ranking influences among 138 different influences to learning Hattie has identified in 2009 (Hattie 2009), shown in Table 10.1, and similarly in 2012 (Hattie 2012), it appears that our effect size

Automobile, Death, Friendship, Nature and Travel (for concepts having shared number of occurrences (two occurrences) we excluded concepts in decreasing alphabetic order).

is only slightly behind the highest-ranking effect size belonging to influence of “self-report grades” in category of “student” having effect size of 1.44 and our effect size is above the second highest-ranking effect size belonging to influence of “Piagetian programs” in category of “student” having effect size of 1.28. In addition our gained effect of 1.38 is much higher than the highest-ranking effect size for influences belonging to category “teaching” that is “providing formative evaluation” having effect size of 0.90 (see Table 10.2).

We want to emphasize that the effect sizes that we have estimated in our experiment do not aim to represent a comparison that contrasts exploration tasks with traditional learning activities happening in a school classroom and thus the effect sizes do not directly represent how much better learning achievement could be expected to be gained with our proposed methods when compared to traditional style of learning at school. Instead, our effect sizes try to contrast learning achievements of active learning process and passive learning process in adoption of knowledge, and with our proposed method the activity is supported by enabling the student to select the hyperlinked concepts to traverse thus adjusting direction of her traversal of exploration path and in the passive alternative that we use for comparison relies on just showing hyperlinked concepts without influence coming from any selection by the student.

We still estimated the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student selects to traverse in experiment group and the hyperlinked concepts shown to her during her traversal of exploration path in control group divided by square root of pooled variance (see Table 10.8). For the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group we got an estimate value of about 1.38 which indicates same kind of effects that we just discussed about concerning the effect size of 1.38 in favor of selected concepts in experiment group in contrast with shown concepts in experiment group. When comparing more precise value for effect sizes it turns out that the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* 1.378442 is a bit lower than the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in experiment group* 1.382165. Since the value of 1.378442 is a bit lower than the value of 1.382165 we suggest that the effects can be considered to be with a similar relative difference greater for the case of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group than for the case of selected concepts in experiment group in contrast with shown concepts in experiment group.

However, since self-reported background information about the students shown in Table 10.4 and Table 10.5 indicated that in control group the distributions of adoption ability and school performance are possibly positioned at a bit lower level than in experiment group these imbalanced characteristics may have contributed to the result that the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group gains greater values than the

effect size in favor of selected concepts in experiment group in contrast with shown concepts in experiment group.

Table 10.6. Estimation of effect size when comparing experiment group with control group.

	Experiment group (n=49)	Control group (n=24)		
Unique hyperlinked concepts shown to the student	34.16327	34		Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student in experimental group and control group 0.011891
Unique recalled hyperlinked concepts	11.32653	11.20833		Effect size in favor of unique shown hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in control group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student in experimental group and control group divided by square root of pooled variance) 0.017281
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student	0.331541	0.329657		
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student	0.01333	0.009401		

Table 10.7. Estimation of effect size when comparing selected hyperlinked concepts in experiment group with shown hyperlinked concepts in experiment group.

	Unique hyperlinked concepts actively selected by the student in experiment group (n=49)	Unique hyperlinked concepts shown to the student in <i>experiment group</i> (n=49)		
Unique hyperlinked concepts	13.79592	34.16327		Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>experiment group</i> 0.052399
Unique recalled hyperlinked concepts	8.938776	11.32653		Effect size in favor of unique selected hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in experiment group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>experiment group</i> divided by square root of pooled variance) 1.382165
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.647929	0.331541		
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.041465	0.01333		

Table 10.8. Estimation of effect size when comparing selected hyperlinked concepts in experiment group with shown hyperlinked concepts in control group.

	Unique hyperlinked concepts actively selected by the student in experiment group (n=49)	Unique hyperlinked concepts shown to the student in control group (n=24)			
Unique hyperlinked concepts	13.79592	34		Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>control group</i>	0.053311
Unique recalled hyperlinked concepts	8.938776	11.20833		Effect size in favor of unique selected hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in control group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>control group</i> divided by square root of pooled variance)	1.378442
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.647929	0.329657			
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.041465	0.009401			

We think that this gives promising support for a claim that learning by browsing conceptual network with our method based on learner-driven exploration can support adopting and thus remembering and learning knowledge with an advantage that is equal or even better than a learning process consisting of being exposed to learning content in a more traditional way like by browsing lecture notes or lecture slides (corresponding to the more monotonic proceeding in knowledge by the control group). Even a further comparison provided extended support for achieving educational gain with our method. With experiment group it appeared that for those concepts that the members had personally actively selected to be traversed in the hyperlink network the recall rate was 65.1 percent, thus it is much more than the percentage of control groups recall rate for all concepts that they were exposed to.

After publishing publication [P7] we have carried out further analysis which has led us to suggest some relatively small changes to the values that we have presented in publication [P7] concerning our results of exploration task. For example, in publication [P7] we reported that the experiment group managed to reproduce about 65 percent of adopted concepts whereas the control group reproduced only about 28 percent, and our further analysis seems to indicate that indeed when concerning hyperlinked concepts that the student selects to traverse during traversal of exploration path the average of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts still should remain as about 65 percent for experiment group but for control group it should be about 33 percent instead of 28 percent. In addition, when concerning hyperlinked concepts that are shown to the student during her traversal of exploration

path, it appeared that for both experiment group and control group the average of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts is near value 33 percent.

We asked the background information after the exploration task so that the student should not be provided with any specific expectations about how to perform in exploration task but on the other hand it is possible that the very recent feeling that the student has just achieved about her personal performance in exploration task can unintentionally affect her aim to estimate for example her general ability to adopt knowledge through reading (i.e. she was asked to estimate her adoption ability in general case, not only in this case of exploration task). Anyway it is possible that since we asked each student to estimate her ability to adopt new knowledge through reading and her success in performing at school this self-reporting may have provided relatively subjective results and it would be useful to carry out additional verifying experiments so that analysis based on these two background characteristics could rely on measuring these two characteristics with more objective and diverse methods than just self-reporting.

We think that it is possible that a more passive type of exploration task offered to control group in contrast with experiment group may have introduced temporarily a bit additional pessimistic feelings to the students of control group that have lead them to give such estimates about adoption ability and school performance that have made response distributions positioned at a bit more towards negative responses than corresponding response distributions of experiment group. We think that it is possible that the effect size in favor of experiment group in contrast with control group can be at least partially induced by the small difference in distributions concerning the student's own estimate about her ability to adopt knowledge through reading (thus in Table 10.4 response distribution of experiment group seems to be positioned at a bit more towards positive responses than corresponding response distributions of control group).

To get more insight about learning process we think that it is important to compare *information that is shown to the learner, information that is encountered (actively selected) by learner and information that is recalled by learner*. To address this we have generated Table 10.9 that enables comparison of 55 concepts of "hyperlink network of 55 concepts" between number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) concepts during exploration (based on Table 5.18). In addition, Appendix Z enables comparison of 55 concepts of "hyperlink network of 55 concepts" between number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique recalled concepts in respect to hyperlinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration. Furthermore, Table 5.18 shows for 55 concepts of "hyperlink network of 55 concepts" the number of revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student.

Table 10.9. Comparison of 55 concepts of “hyperlink network of 55 concepts” between number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) concepts during exploration.

Number of times hyperlinked concepts are shown to student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique encountered (actively selected) concepts in exploration path of 20 steps when each concept counted at most once for each student in <i>experiment group</i> (n=49) (based on Table 5.18)		
<i>Concept</i>	<i>Number of times shown for all students</i>	<i>Average number of times shown per each student</i>	<i>Concept</i>	<i>Number of unique recalled selected concepts by all students</i>	<i>Average number of unique recalled selected concepts per each student</i>	<i>Concept</i>	<i>Number of unique encountered (actively selected) concepts by all students</i>	<i>Average number of unique encountered (actively selected) concepts per each student</i>
Human	263	5.367346939	Emotion	24	0.489795918	Love	30	0.612244898
Family	243	4.959183673	Love	24	0.489795918	Emotion	28	0.571428571
Biology	234	4.775510204	Happiness	22	0.448979592	Human	28	0.571428571
Oxygen	222	4.530612245	Human	18	0.367346939	Experience	26	0.530612245
Happiness	199	4.06122449	Organism	18	0.367346939	Happiness	26	0.530612245
Love	198	4.040816327	Biology	17	0.346938776	Adolescence	25	0.510204082
Emotion	185	3.775510204	Family	17	0.346938776	Biology	23	0.469387755
Organism	180	3.673469388	Joy	16	0.326530612	Family	23	0.469387755
Animal	179	3.653061224	Education	15	0.306122449	Education	22	0.448979592
Religion	173	3.530612245	Adolescence	14	0.285714286	Death	21	0.428571429
Plant	161	3.285714286	Animal	13	0.265306122	Organism	21	0.428571429
Adolescence	156	3.183673469	Death	13	0.265306122	Diet_(nutrition)	20	0.408163265
Sibling	153	3.12244898	Mother	13	0.265306122	Disease	20	0.408163265
Old_age	128	2.612244898	Oxygen	12	0.244897959	Health	19	0.387755102
Health	127	2.591836735	Disease	11	0.224489796	Joy	19	0.387755102
Child	125	2.551020408	Water	11	0.224489796	Animal	17	0.346938776
Diet_(nutrition)	123	2.510204082	Father	10	0.204081633	Parent	17	0.346938776
War	121	2.469387755	Plant	10	0.204081633	Plant	17	0.346938776
Leisure	113	2.306122449	War	10	0.204081633	Child	16	0.326530612
Joy	93	1.897959184	Health	9	0.183673469	Friendship	16	0.326530612
Education	92	1.87755102	School	9	0.183673469	Nature	16	0.326530612
Disease	91	1.857142857	Sibling	9	0.183673469	Oxygen	16	0.326530612
God	90	1.836734694	Friendship	8	0.163265306	Heart	15	0.306122449
Sun	86	1.755102041	Sun	8	0.163265306	Learning	15	0.306122449
Father	84	1.714285714	Teacher	8	0.163265306	Mother	15	0.306122449
Heart	83	1.693877551	Child	7	0.142857143	War	13	0.265306122
House	82	1.673469388	Heart	7	0.142857143	Sibling	12	0.244897959
Water	82	1.673469388	Learning	7	0.142857143	Father	11	0.224489796
Clothing	80	1.632653061	Nature	7	0.142857143	Sun	11	0.224489796
Music	80	1.632653061	Peace	7	0.142857143	Water	11	0.224489796
Nature	80	1.632653061	Religion	7	0.142857143	Leisure	10	0.204081633
Mother	74	1.510204082	Tree	7	0.142857143	Religion	10	0.204081633
Death	62	1.265306122	Leisure	6	0.12244898	School	9	0.183673469
Parent	55	1.12244898	Parent	6	0.12244898	Teacher	9	0.183673469
School	53	1.081632653	God	5	0.102040816	Peace	8	0.163265306
Teacher	52	1.06122449	Diet_(nutrition)	4	0.081632653	Sea	7	0.142857143
Television	52	1.06122449	Old_age	4	0.081632653	Television	7	0.142857143
Experience	49	1	Sea	4	0.081632653	Tree	7	0.142857143
Friendship	47	0.959183673	Experience	3	0.06122449	Light	6	0.12244898
Learning	44	0.897959184	Travel	3	0.06122449	Birth	5	0.102040816
Light	29	0.591836735	Work	3	0.06122449	God	5	0.102040816
Tree	28	0.571428571	Automobile	2	0.040816327	Old_age	5	0.102040816
Food	23	0.469387755	Birth	2	0.040816327	Work	5	0.102040816
Automobile	21	0.428571429	Home	2	0.040816327	Clothing	3	0.06122449
Travel	21	0.428571429	House	2	0.040816327	Travel	3	0.06122449
Birth	17	0.346938776	Clothing	1	0.020408163	Automobile	2	0.040816327
Sea	14	0.285714286	Light	1	0.020408163	Home	2	0.040816327
Peace	13	0.265306122	Music	1	0.020408163	House	2	0.040816327
Work	11	0.224489796	Television	1	0.020408163	Food	1	0.020408163
Home	2	0.040816327	Cat	0	0	Music	1	0.020408163
Computer	1	0.020408163	Computer	0	0	Cat	0	0
Cat	0	0	Dog	0	0	Computer	0	0
Dog	0	0	Food	0	0	Dog	0	0
Pet	0	0	Pet	0	0	Pet	0	0
Telephone	0	0	Telephone	0	0	Telephone	0	0

Based on Table 10.9 we can make some coarse estimates about dependencies that can influence adoption of new knowledge when a learner traverses hyperlinks in a conceptual network. Since during exploration task each member of experiment group (49 persons) traversed an exploration path containing 20 steps and thus on average 34.16 unique concepts were shown to each student and after the experiment the student could recall on average 11.33 unique concepts (about 33.2 percent) we can take from Table 10.9 into further analysis three sets of *eleven highest-ranking concepts* in respect to three properties that are *shown hyperlinked concepts*, *recalled selected hyperlinked concepts* and *encountered (actively selected) hyperlinked concepts*.

Therefore in decreasing order eleven highest-ranking concepts based on the number of times hyperlinked concepts are shown to student during her traversal of exploration path include Human, Family, Biology, Oxygen, Happiness, Love, Emotion, Organism, Animal, Religion and Plant. Similarly in decreasing order eleven highest-ranking concepts based on the number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during her traversal of exploration path include Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal (at the eleventh ranking position there were three concepts having shared number of recalled concepts including Animal, Death and Mother, each having 13 occurrences, but to enable comparison of three equally sized sets of eleven concepts we decided to select here only one of them in ascending alphabetic order and thus in the following analysis only Animal is considered to represent the eleventh ranking position). Also similarly in decreasing order based on the number of unique encountered (actively selected) hyperlinked concepts in exploration path when each concept counted at most once for each student include Love, Emotion, Human, Experience, Happiness, Adolescence, Biology, Family, Education, Death and Organism.

All these three high-ranking vocabulary sets share seven concepts of eleven concepts (about 64 percent) including Emotion, Love, Happiness, Human, Organism, Biology and Family, and additionally set of recalled selected concepts and set of encountered (actively selected) concepts share two concepts including Education and Adolescence, and set of recalled selected concepts and set of shown concepts share one concept including Animal. To coarsely estimate distance of revisiting a certain concept in exploration path for each of just mentioned shared seven concepts of eleven concepts it turned out that with paths having two occurrences of one of these concepts the average distance was 4.0 intermediary concepts (on average 2.5 for Emotion, 2.5 for Love, 1.0 for Happiness, 7.4 for Human, 3.7 for Organism, 4.9 for Biology and 5.8 for Family).

These shared seven concepts of eleven concepts have quite dominant role also in two additional vocabulary sets: all of these seven concepts belong to eleven highest-ranking concepts in respect to the number of unique recalled concepts in respect to hyperlinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration (shown in Appendix Z), and six of these seven concepts belong to eleven highest-ranking concepts in respect to the number of revisits to concepts in exploration paths when for each concept at most one revisit can be counted

for each student (shown in Table 5.18) when observing 55 concepts of “hyperlink network of 55 concepts”.

Figure 10.1 shows all 28 connecting hyperlinks (black solid arcs) between the set of eleven highest-ranking concepts of recalled selected concepts (red concepts) in “hyperlink network of 55 concepts” containing altogether 212 hyperlinks. In addition the figure is supplied with five additional concepts of which three belong to the set of eleven highest-ranking concepts of shown concepts (purple concepts Oxygen, Religion and Plant) and two belong to the set of eleven highest-ranking concepts of encountered (actively selected) concepts (turquoise concepts Experience and Death). 17 green dotted arcs show all hyperlinks connecting between these five additional concepts and connecting these five additional concepts to set of eleven highest-ranking concepts of recalled selected concepts in “hyperlink network of 55 concepts”. Seven concepts that are shared by all three high-ranking vocabulary sets of eleven concepts (recalled selected concepts, shown concepts and encountered (actively selected) concepts) are indicated with an asterisk (*).

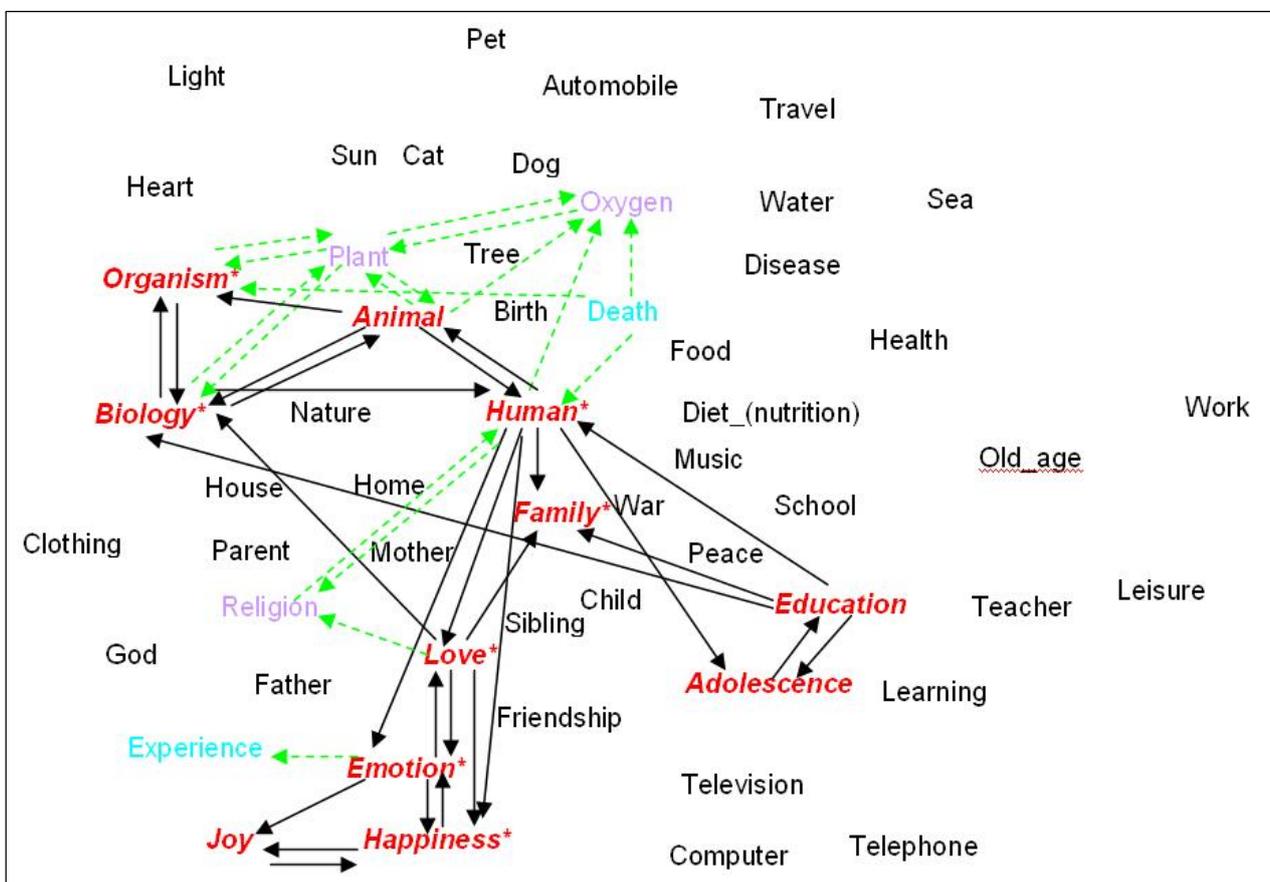


Figure 10.1. This figure shows all 28 connecting hyperlinks (black solid arcs) between the set of eleven highest-ranking concepts of recalled selected concepts (red concepts) in “hyperlink network of 55 concepts” containing altogether 212 hyperlinks. In addition the figure is supplied with five additional concepts of which three belong to the set of eleven highest-ranking concepts of shown concepts (purple concepts) and two belong to the set of eleven highest-ranking concepts of encountered (actively selected) concepts (turquoise concepts). 17 green dotted arcs show all hyperlinks connecting between these five additional concepts and connecting these five additional concepts to set of eleven highest-ranking concepts of recalled selected concepts in “hyperlink network of 55 concepts”. Seven concepts that are shared by all three high-ranking vocabulary sets of eleven concepts (recalled selected concepts, shown concepts and encountered (actively selected) concepts) are indicated with an asterisk (*).

We suggest that in Figure 10.1 eleven highest-ranking recalled selected concepts and connecting hyperlinks between them can possibly coarsely represent how memories and cumulative understanding is formed in human mind during a learning process so that a learner is exposed to a set of concepts that is in current case represented by a set of 55 concepts and that depending on various properties of learning session and amount of exposure some relationships become established and reinforced between certain pairs of concepts inside this set of 55 concepts. We think that here eleven highest-ranking recalled selected concepts and connecting hyperlinks between them can be seen to form an *emerging fundamental grid for a conceptual network* that offers a convenient cluster structure so that information can be managed efficiently in a compact and easily updateable form in human mind. We think that in Figure 10.1 five additional concepts (three shown concepts and two encountered (actively selected) concepts) and linkage between them and connecting them to the set of eleven highest-ranking recalled selected concepts can be seen as a potential area for cumulative future growth of the fundamental grid for a conceptual network so that these five additional concepts could possibly become adopted next and thus could become then considered as recalled selected concepts as well.

We suggest that knowledge adoption in human mind could gradually proceed during learning process so that eventually all 55 concepts could have become connected to same entity of fundamental grid for a conceptual network in a way that resulting conceptual network could somewhat resemble “hyperlink network of 55 concepts” that we have generated based on hyperlink network of the Wikipedia containing 212 hyperlinks connecting 55 concepts as shown in Appendix J. Naturally different learners and learning processes can lead to different network structures and there can be various parallel, overlapping and multidimensional conceptual networks in human mind to represent knowledge but we suggest that fundamental principles governing knowledge adoption and management in human mind can be based on structures and processes we have proposed with a conceptual network model that is illustrated with an example that we refer to as “hyperlink network of 55 concepts”.

It is interesting to note that while each student made in “hyperlink network of 55 concept” an exploration path traversing 20 hyperlink steps she eventually managed to recall on average 11.33 unique concepts of on average 34.16 unique shown concepts (each shown on average 5.08 times) and when observing linkage between a set of eleven highest-ranking recalled selected concepts of all 49 students participating the experiment there were 28 connecting hyperlinks between these eleven highest-ranking recalled selected concepts (so number of steps (20) appears to be relatively close to number of connecting hyperlinks (28)).

While among all 55 concepts of “hyperlink network of 55 concepts” there is on average 3.85 departing hyperlinks and 3.85 arriving hyperlinks interconnecting these 55 concepts (shown in Table 5.12), the set of eleven highest-ranking recalled selected concepts (Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal) has on average 5.82 departing hyperlinks and 6.64 arriving hyperlinks connecting to 55 concepts of “hyperlink network of 55 concepts”.

Furthermore, five additional concepts that we think might possibly become adopted next (Oxygen, Religion, Plant, Experience and Death) have on average 4.8 departing hyperlinks and 6.2 arriving hyperlinks connecting to 55 concepts of “hyperlink network of 55 concepts”. We suggest that here higher average amount of interconnecting links for recalled selected concepts indicates that it is easier to recall such concepts that have highly linked position in hyperlink network of vocabulary and thus these concepts can have diverse associative paths to other concepts and can get high number of visits during exploration in hyperlink network possibly due to serving as some kind of hub in the network.

Figure 10.1 can be compared with Figure 6.3 showing 55 concepts primarily supplied with highest-ranking departing hyperlink and highest-ranking arriving hyperlink in respect to five alternative statistical features of corresponding Wikipedia articles (including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and edits per article size). It seems that the set of eleven highest-ranking recalled selected concepts are relatively highly inter-connected also based on hyperlinks listed in Figure 6.3 which might indicate that also properties of five alternative statistical features can have some kind of contribution to which concepts can become recalled well after exploration in hyperlink network. Also it is possible that recalling a concept after exploration in hyperlink network depends on what is the ranking of this concept in general high-frequency word list of current language and at how early in life and how much a person has become exposed to this concept and how meaningful it is to him personally, as motivated by previous research ((Izura and Ellis 2002); (Ellis and Lambon 2000)).

Among the set of eleven highest-ranking recalled selected concepts there appears to be on average 4.64 interconnecting hyperlinks (2.36 departing hyperlinks and 2.27 arriving hyperlinks) for each of eleven concepts: Human (7 hyperlinks: 5 departing + 2 arriving), Love (6 hyperlinks: 4 departing + 2 arriving), Emotion (6 hyperlinks: 3 departing + 3 arriving), Happiness (6 hyperlinks: 2 departing + 4 arriving), Education (5 hyperlinks: 4 departing + 1 arriving), Animal (5 hyperlinks: 3 departing + 2 arriving), Biology (5 hyperlinks: 2 departing + 3 arriving), Adolescence (3 hyperlinks: 1 departing + 2 arriving), Joy (3 hyperlinks: 1 departing + 2 arriving), Family (3 hyperlinks: 0 departing + 3 arriving), and Organism (2 hyperlinks: 1 departing + 1 arriving).

Based on Table 10.9 and Table 10.7 in “hyperlink network of 55 concept” an exploration path while traversing 20 hyperlink steps offers for the student on average 101.51 shown concepts (of which 34.16 are unique concepts meaning showing each of them about 2.97 times), thus on average 5.08 shown concepts per each hyperlink step (i.e. at each concept there are on average 5.08 alternative hyperlinked concepts available to be traversed next), and along traversing 20 hyperlink steps the student encounters on average 13.80 unique (actively selected) concepts meaning encountering each of them on average 1.45 times. Based on Table 10.9 we estimated that for the set of eleven highest-ranking recalled selected concepts (Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal) each of these eleven concepts is shown (i.e. not necessarily actively selected but shown) along exploration path of 20 hyperlink steps on average 3.75 times, thus on average 0.19 times

shown per each hyperlink step, and is encountered (actively selected) along exploration path of 20 hyperlink steps on average 0.49 times, thus on average 0.02 times per each hyperlink step.

Based on Table 10.7 it can be also seen that student can recall on average 11.33 unique concepts of 34.16 unique shown concepts (33 percent of unique shown concepts), and can recall on average 8.94 unique concepts of those unique shown concepts that are also actively selected (26 percent of unique shown concepts). It appears that about 79 percent ($8.94/11.33 \approx 0.79$) of unique recalled concepts are actively selected along exploration path and remaining 21 percent are just shown during exploration path but not actively selected. Anyway student on average can recall 8.94 unique concepts of 13.80 unique encountered (actively selected) concepts thus meaning that she can recall 65 percent of unique encountered (actively selected) concepts.

When estimating from Table 10.9 for the three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” what is the range of average amount of interaction with each set of concepts for each of 49 students along exploration path, it appears that eleven highest-ranking shown concepts are shown on average 3.29–5.37 times per each student, eleven highest-ranking recalled selected concepts are recalled on average 0.27–0.49 times per each student, and eleven highest-ranking encountered (actively selected) concepts are encountered (actively selected) on average 0.43–0.61 times per each student. Even if the three sets of eleven highest-ranking concepts do not share exactly same concepts (sharing 7 of 11 concepts) we think that these values can possibly indicate a somewhat minimal level of interaction that a student should have with concepts along exploration path so that these concepts can be sufficiently become adopted. We think that especially interesting is that when considering eleven highest-ranking recalled selected concepts and their corresponding values of average number of times they are shown per each student, nine of these have been shown at least 3.18 times and two concepts additionally gained a bit lower values (Education shown 1.88 times and Joy shown 1.90 times).

Some of the estimates about properties of exploration paths in hyperlink network that have been gained in exploration task and that have been just discussed are shown in Table 10.10. Please note that just discussed features related to three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and features shown in Table 10.10 can be considered to at least indirectly give strong experimental support to our suggestions of Publication [P7] (as will be discussed in Subchapter 11.1) that the student’s exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning. We have carried out an extended analysis just discussed in this current Subchapter 10.1 after publishing publication [P7] and therefore our these supplementing later experiments seem to fruitfully verify findings of our earlier preliminary testing we reported in publication [P7] including suggested approximate values for parameters of the proposed framework for spaced learning with exploration in hyperlink network of the Wikipedia.

Based on Table 10.9 for each of five comparison tests Table 10.11 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating *degrees of dependency* between 55 concepts of “hyperlink

network of 55 concepts” based on three rankings: number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration and number of unique encountered (actively selected) concepts during exploration.

Table 10.10. Some estimates about properties of exploration paths in hyperlink network that have been gained with experiment group (n=49) of exploration experiment.

When a student traverses an exploration path containing 20 hyperlink steps inside “hyperlink network of 55 concepts”
- “hyperlink network of 55 concepts” contains 212 hyperlinks connecting 55 concepts based on hyperlink network of the Wikipedia
- along 20 hyperlinks steps of exploration path at each concept there are on average 5.08 alternative hyperlinked concepts available to be traversed next
- along 20 hyperlinks steps there are on average 101.51 shown concepts (of which on average 34.16 are unique concepts meaning showing each of them about 2.97 times)
- from the set of 34.16 unique shown concepts about 11.33 can be recalled
- along 20 hyperlinks steps on average 13.80 unique concepts become actively selected meaning selecting each of them about 1.45 times
- from the set of 13.80 unique actively selected concepts about 8.94 can be recalled
- student can recall about 11.33 unique concepts of 34.16 unique shown concepts (33 percent of unique shown concepts); - student can recall about 8.94 unique concepts of those unique shown concept that are also actively selected (26 percent of unique shown concepts); - thus about 79 percent (8.94/11.33) of unique recalled concepts are actively selected along exploration path and remaining about 21 percent are just shown but not actively selected; - student can recall about 8.94 unique concepts of 13.80 unique actively selected concepts (65 percent of unique actively selected concepts)
- corresponding to recalled 11.33 unique shown concepts it was estimated that eleven highest-ranking shown concepts are shown on average 3.29–5.37 times per each student, eleven highest-ranking recalled selected concepts are recalled on average 0.27–0.49 times per each student, and eleven highest-ranking actively selected concepts are actively selected on average 0.43–0.61 times per each student

To facilitate identifying possible similarities between frequency distributions of Table 10.9 we transformed for representation of Table 10.11 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of times hyperlinked concepts are shown to student during exploration has a weighting parameter 1; scaled frequency distribution of number of recalled concepts in respect to hyperlinked concepts that are shown to student during exploration has a weighting parameter 11; and scaled frequency distribution of number of encountered concepts during exploration has a weighting parameter 7. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 10.11. Degrees of dependency between 55 concepts of “hyperlink network of 55 concepts” based on three rankings: number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration and number of unique encountered (actively selected) concepts during exploration.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of times hyperlinked concepts are shown to student during exploration (scaled)	number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p= 0.899 (null hypothesis Hks not rejected)	gamma= 0.6139106 (standard error 0.1559587); null hypothesis Hgk rejected (p= 8.272444x10 ⁻⁰⁵)	rho= 0.7766964; null hypothesis Hsr rejected (p= 3.184x10 ⁻¹²)	tau= 0.5993631; null hypothesis Hkr rejected (p= 2.949x10 ⁻¹⁰)
number of times hyperlinked concepts are shown to student during exploration (scaled)	number of unique encountered concepts during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p= 0.899 (null hypothesis Hks not rejected)	gamma= gamma: 0.5879888 (standard error 0.1585215); null hypothesis Hgk rejected (p= 0.0002079098)	rho= 0.7495532; null hypothesis Hsr rejected (p= 4.576x10 ⁻¹¹)	tau= 0.5785372; null hypothesis Hkr rejected (p= 9.067x10 ⁻¹⁰)
number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration (scaled)	number of unique encountered concepts during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p= 0.899 (null hypothesis Hks not rejected)	gamma= 0.7570499 (standard error 0.1302929); null hypothesis Hgk rejected (p= 6.233561x10 ⁻⁹)	rho= 0.8614709; null hypothesis Hsr rejected (p < 2.2x10 ⁻¹⁶)	tau= 0.7342476; null hypothesis Hkr rejected (p= 2.243x10 ⁻¹⁴)

We examined how the student’s performance on recalling hyperlinked concepts was related to different background parameters gained together with the student’s response. Table 10.12 shows recalling performance in respect to the gender of the student. Table 10.13 shows recalling performance in respect to comparing the adoption of knowledge through reading with the method to traditional learning from book. Table 10.14 shows recalling performance in respect to if the student is interested in using the method for adoption of knowledge trough reading. Table 10.15 shows recalling performance in respect to how easy it is for the student to adopt knowledge through reading. Table 10.16 shows recalling performance in respect to the students school performance.

Table 10.12. Recalling hyperlinked concepts in respect to gender of the student.

Gender	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Male and female	49	0.331541	0.01333	49	0.647929	0.041465
Male	18	0.274824	0.002635	18	0.587936	0.015385
Female	31	0.364474	0.016784	31	0.682764	0.054213
Gender	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Male and female	24	0.329657	0.009401			
Male	12	0.289216	0.006737			
Female	12	0.370098	0.009352			

Table 10.13. Recalling hyperlinked concepts in respect to response to question: “If you compare to traditional learning from a book, then the method you have tried for adopting knowledge through reading appears to be...”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Somewhat more or much more useful	27 (23+4)	0.341497	0.014961	27 (23+4)	0.687267	0.042991
Equally useful	15	0.314178	0.014378	15	0.570217	0.047187
Somewhat less or much less useful	7 (6+1)	0.330346	0.007058	7 (6+1)	0.662722	0.01301
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Somewhat more or much more useful	8 (6+2)	0.3125	0.013825			
Equally useful	10	0.323529	0.006728			
Somewhat less or much less useful	6 (5+1)	0.362745	0.009919			

Table 10.14. Recalling hyperlinked concepts in respect to response to question: “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
It is probable or very probable	24 (20+4)	0.326862	0.010406	24 (20+4)	0.682569	0.038797
Perhaps	21	0.330346	0.019033	21	0.600592	0.049464
It is improbable or very improbable	4 (2+2)	0.36589	0.004855	4 (2+2)	0.688609	0.008757
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
It is probable or very probable	5 (3+2)	0.317647	0.008391			
Perhaps	12	0.291667	0.00715			
It is improbable or very improbable	7 (5+2)	0.403361	0.007991			

Table 10.15. Recalling hyperlinked concepts in respect to response to question: “How easy it is for you to adopt new knowledge through reading?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	n_i	Average	Variance	n_i	Average	Variance
Easy or very easy	24 (21+3)	0.368329	0.012138	24 (21+3)	0.709751	0.031972
Moderate	18	0.295964	0.01521	18	0.575855	0.054687
Difficult or very difficult	7 (5+2)	0.296894	0.006406	7 (5+2)	0.621302	0.022518
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	n_i	Average	Variance			
Easy or very easy	7 (6+1)	0.336134	0.002842			
Moderate	15	0.319608	0.012589			
Difficult or very difficult	2 (2+0)	0.382353	0.015571			

Table 10.16. Recalling hyperlinked concepts in respect to response to question: “In your opinion, how successfully do you perform at school?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	n_i	Average	Variance	n_i	Average	Variance
Well or excellently	23 (18+5)	0.370344	0.014691	23 (18+5)	0.693337	0.038606
Satisfactorily	22	0.316661	0.006254	22	0.652367	0.027021
Fairly or faintly	4 (4+0)	0.190263	0.021991	4 (4+0)	0.362426	0.066552
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	n_i	Average	Variance			
Well or excellently	10 (9+1)	0.35	0.014504			
Satisfactorily	14	0.315126	0.006046			
Fairly or faintly	0 (0+0)	0	0			

10.2. Adoption of vocabulary

Features of a learning process to adopt vocabulary of a language are naturally strongly language dependent, affected among other things by morphology, variants of dialects, conjugation and syntax. In our work we have decided to focus on findings concerning vocabulary of English language due to its dominant international position. In publications of previous research it appears that used terminology remains sometimes fuzzy and that parallel observations are not easy to compare. For example in research concerning human vocabulary it seems that term word is sometimes used when actually meaning a word family and thus some effects of this kind of unclarities may have also somewhat affected accuracy of conclusions that we have tried to do based on previous research.

Nation and Waring (Nation & Waring 1997) estimated that in *English lexicon* there are well over 54000 word families and an *educated adult native speaker* knows around 20000 of them. According to Nation and Waring (Nation & Waring 1997) however, the most frequent 3000 to 5000 word families typically cover around 90 percent of ordinary text and even more of spoken language, and thus mastering just this fraction of full

vocabulary can already provide a strong basis for comprehension thus allowing efficient further learning from the context.

Thal et al. (Thal et al. 1997) have experimentally measured mean number of *produced words* at each month during child's development ranging from 8-month-old to 30-month-old. When we visually interpreted from graph in publication of Thai et al (Thal et al. 1997) representing vocabulary for children classified having an average progress we concluded following coarse estimates: 8-month-olds can produce about 0 words, 12-month-olds can produce about 10 words, 18-month-olds about 120 words, 24-month-olds about 400 words and 30-month-olds 560 words. Despite of somewhat confusing notations we visually interpreted from graph in publication Thai et al (Thal et al. 1997) also following estimates for the number of *words that can be considered to be understood* by young children: 8-month-olds can understand about 25 words, 12-month-olds can understand 90 words and 16-month-olds can understand 200 words.

Bloom (Bloom 2000) suggests that the *rate of learning new words* can be represented with following estimates: for ages 12–16 months 0.3 words per day, for ages 16–23 months 0.8 words per day, for ages 23–30 months 1.6 words per day, for ages from 30 months to 6 years 3.6 words per day, for ages 6–8 years 6.6 words per day and for ages 8–10 years 12.1 words per day. When continuing from produced vocabulary of 400 word for 2-year-olds previously identified based on Thal et al. (Thal et al. 1997) these growing rates can be used to generate estimates that vocabulary is for a 3-year-old about 1350 words, for a 4-year-old about 2670 words and for a 5-year-old about 3990 words.

Nation and Waring (Nation & Waring 1997) estimated that a *five-year-old child* starting school has vocabulary of about 4000–5000 word families and every year a native speaker adds about 1000 word families to her vocabulary (corresponding to about 2.7 word families per day) until a university graduate has about 20000 word families in her vocabulary. On the other hand, D'Anna et al. (D'Anna et al. 1991) estimated that a *college student* knows about 16785 different words. Nation (Nation 2006) reports that highly educated people studying advanced degrees through use of *non-native English language* have a receptive English vocabulary of approximately 8000–9000 word families. Lehr et al. (Lehr et al. 2004) conclude based on earlier research that students add about 2000–3500 distinct words every year to their *reading vocabulary* ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)) or alternatively 600–1200 new root word meanings in every year of elementary school ((Biemiller & Slonim 2001); (Anglin 1993)).

Lehr et al. (Lehr et al. 2004) emphasize earlier results that *school texts* from grade 3 through grade 9 contain about 88500 distinct word families (Nagy & Andersson 1984) but however that classroom intervention studies indicate that at school at most 8 to 10 new words can be taught effectively every week, meaning at most 400 new words per year (Stahl & Fairbanks 1986). Thus when contrasting these rates with estimated yearly adoption of 2000–3500 distinct words for students mentioned by Lehr et al. (Lehr et al. 2004), it can be estimated that a lot of remaining about 1600–3100 new words yearly or about 4–8 new words daily becomes adopted *outside direct teaching*. Similarly Kuhn and Stahl (Kuhn & Stahl 1998) conclude based on earlier research that in school

between kindergarten and 12th grade people are exposed to about 88700 word families (Nagy & Andersson 1984) and about 45000 of them are learned thus learning about 3000 new words per year ((Graves 1986); (White et al. 1990)) but that only about 300–400 words can be learned through direct instruction per year (Stahl 1991). These numbers seem to suggest that students can be expected to learn about 60 words per week and of which about 6–8 words through direct instruction, and that about 2600–2700 words per year become adopted outside direct teaching.

As already mentioned in Chapter 2, a power function formula $y=mx^b$ can be suggested to explain how much time in seconds (y) is needed to recognize precisely information that has been presented to a person after various amounts of exposures (x) concerning this information so that parameters m and b can be defined to address a particular type of learning situation ((Marzano 2000) referring to Anderson (Anderson 1995)).

Baker et al. (Baker et al. 1992) mention based on earlier research that especially at primary grades at school students learn 3000 new words per year thus corresponding about 8 words per day ((Baumann & Kameenui 1991); (Beck & McKeown 1991); (Graves 1986)). In addition, Baker et al. (Baker et al. 1992) mention earlier research showing that in a collection of 5044 words *disadvantaged first graders* knew about 1800 words and *middle-class students* about 2700 words, and in a collection of 19050 words *disadvantaged first graders* knew about 2900 words and *middle-class first graders* about 5800 words (Graves et al. 1982). Furthermore, Baker et al. (Baker et al. 1992) mention earlier research showing that in a collection of 19050 words *first graders* of two low socio-economic status school knew about 2500 words and about 3500 words and in a collection of 19050 words *first graders* of a middle socio-economic status school knew about 4800 words, and along grades 1–4 the students of two low socio-economic status school learned about 3500 words per year and the students of a middle socio-economic status school learned about 5200 words per year (White et al. 1990).

Dupuy (Dupuy 1974) has estimated that there are 12300 basic words in English and that 7800 of these words are necessary for educational purposes for learners ranging from kindergarten to grade 12 thus requiring direct instruction of under 650 words per each year. Following suggestions of Dupuy a list of 8109 basic words was created by Becker et al. (Becker et al. 1980). It has been estimated that starting from age of two years a child masters about 10 new words per day thus reaching a vocabulary of about 14000 words by age of six years (Clark 1993). In addition, it has been estimated that at grade 1 a child knows about 6000 words but recognizing them in print is so much harder that she recognizes in print only 3000 of them when she is at grade 4 (Chall 1987). Furthermore it has been estimated that an adult knows 25 percent more words that she uses in her speaking or writing (Crystal 1995). Also, it was found that in a sample of 9000 words of elementary school 72 percent of words had more than one meaning (Johnson et al. 1983).

Some estimates about properties of adoption of vocabulary that have been just discussed are shown in Table 10.17.

Table 10.17. Some estimates about properties of adoption of vocabulary.

<i>Parameter concerning adoption of vocabulary</i>	<i>Values found in previous research for this parameter</i>
vocabulary of a child	25 understood words (8-month-old child) (interpreted visually from graph in Thal et al. 1997); 90 understood words and 10 produced words (12-month-old child) (interpreted visually from graph in Thal et al. 1997); 200 understood words (16-month-old child) (interpreted visually from graph in Thal et al. 1997); 120 produced words (18-month-old child) (interpreted visually from graph in Thal et al. 1997); 400 produced words (24-month-old-child) (interpreted visually from graph in Thal et al. 1997); 560 produced words (30 month-old child) (interpreted visually from graph in Thal et al. 1997); 1350 word (3-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 2670 words (4-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 3990 words (5-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 4000–5000 word families (5-year-old child) (Nation & Waring 1997); 14000 words (6-year-old child) (Clark 1993); 6000 words that are known (child at grade 1) (Chall 1987); 3000 words that can be recognized in print (child at grade 4) (Chall 1987)
vocabulary of an adult	20000 word families (university graduate) (Nation & Waring 1997); 16785 words (college student) (D’anna et al. 1991); 45000 words (learned between kindergarten and grade 12) ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990))
sufficient vocabulary for a non-native adult	8000–9000 word families (Nation 2006)
encountered word families or words during school years	88500 word families encountered between grade 3 and grade 9 ((Lehr et al. 2004) referring to (Nagy & Andersson 1984)); 88700 word families encountered between kindergarten and grade 12 ((Kuhn & Stahl 1998) referring to (Nagy & Andersson 1984)); 12300 basic words of which 7800 words considered necessary for educational purposes from kindergarten to grade 12 (Dupuy 1974)
rate of learning new words	0.3 words per day (ages 12–16 months) (Bloom 2000); 0.8 words per day (ages 16–23 months) (Bloom 2000); 1.6 words per day (ages 23–30 months) (Bloom 2000); 3.6 words per day (ages from 30 months to 6 years) (Bloom 2000); 6.6 words per day (ages 6–8 years) (Bloom 2000); 12.1 words per day (age of 8–10 years) (Bloom 2000); about 10 words per day (starting form age of 2 years in early years) (Clark 1993); 1000 word families per year (from age of 5 years to age of an university graduate) (Nation & Waring1997); 2000–3500 words per year ((Lehr et al. 2004) referring to ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)); 600–1200 root word meanings per year ((Lehr et al. 2004) referring to ((Biemiller & Slonim 2001); (Anglin 1993)); 3000 words per year ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990)); 60 words per week (estimated based on (Kuhn & Stahl 1998)); 3000 words per year or 8 words per day (primary grades of school) ((Baker et al. 1992) referring to ((Baumann & Kameenui 1991); (Beck & McKeown 1991); (Graves 1986)); 3500 words per year (grades 1–4 in low socio-economy status school) and 5200 words per year (grades 1–4 in middle socio-economy status school) ((Baker et al. 1992) referring to (White et al. 1990))
new words learned through active teaching	at most 400 words per year or at most 8–10 new words per week ((Lehr et al. 2004) referring to (Stahl & Fairbanks 1986)); 300–400 words per year ((Kuhn & Stahl 1998) referring to (Stahl 1991)); 6–8 words per week (estimated based on (Kuhn & Stahl 1998)); under 650 words per each year (Dupuy 1974);
new words learned outside active teaching	1600–3100 words per year or 4–8 new words per day (estimated based on (Lehr et al. 2004)); 2600–2700 words per year (estimated based on (Kuhn & Stahl 1998))

10.3. Exposure required for learning

Nation and Waring (Nation & Waring 1997) conclude based on earlier research by Laufer (Laufer 1989) that about *95 percent coverage* is sufficient for reasonable comprehension of text meaning that density of unknown words in text can be at most be around one in every 20 encountered words. This coverage can be reached especially in favourable tailored textual contexts with 3000–5000 word families or just 2000–3000 word families. Wozniak and Gorzelanczyk (Wozniak & Gorzelanczyk 1994) suggested a computational method to assist paired-associate learning by offering items to the learner so that inter-repetition intervals are optimized so that 5 percent of to-be-remembered items are not remembered at the moment of repetition. Hu and Nation (Hu & Nation 2000) experimentally found out that when reading fictional texts with strong chronological storyline without having access to dictionary or glossary (i.e. unassisted reading) most of the learners need to know *98 percent of the words* to get an adequate comprehension of the text. Thus the density of unknown words should not be greater than one in fifty words to maintain comprehension in reading.

Carver (Carver 1994) showed that when providing text passages of varied difficulty to students at grades 3–6 and graduate students, easy texts contained close to 0 percent unknown basic words, difficult texts 2 percent or more unknown basic words, and texts matched closely to learners ability about 1 percent unknown basic words. Based on British National Corpus, Nation (Nation 2006) has created fourteen consecutive *high-frequency lists* in sets of 1000 word families (word families having rank 1–1001, word families having rank 1001–2000, etc.) and with them found estimates for vocabulary sizes needed for sufficient comprehension in various forms of reading and listening.

Laufer and Ravenhorst-Kalakovski (Laufer & Ravenhorst-Kalakovski 2010) suggest based on empirical analysis that for independent reading comprehension second language learners should have a vocabulary of about 8000 words offering about 98 percent text coverage and for reading comprehension with some guidance and help they should have a vocabulary of about 4000–5000 words offering about 95 percent text coverage. Hsu (Hsu 2009) mentions earlier research (Carroll et al. 1971) that studied a collection of varied texts written for children in grades 3–9 containing 5 million words identifying that there were 86741 unique words, and furthermore it was found that 2000 most popular words can make a 80 percent coverage of word usage in longer texts and 5000 most popular words a 90 percent coverage, and correspondingly to have 95 percent coverage seems to require about 12000 words.

Based on the range of high-frequency words that follow original Zipf's law it appears that a *core vocabulary of English texts* can be considered to contain about 7873 words that have an exponential decay with a rate of about 30 words per year and a half-life of about 200 years (Gerlach & Altmann 2013). Lehr et al. (Lehr et al. 2004) also mention earlier findings that to convey actual content words about 50 percent of English text consists of only 107 *function words* like “are”, “that”, “a” and “to” (Zeno et al. 1995) and that it was identified that text in children's books can have twice as much infrequently used or rare words than even conversation among college graduates (Hayes & Ahrens 1988). Language in the society is in a constant change and new concepts and

meanings can be defined in almost unlimited way although meanwhile letting unused concepts and meanings to become obsolete.

Kilgarriff (Kilgarriff 1997) identified 6318 lemmatized words of British National Corpus that occur more than (or at least) 800 times. Chujo (Chujo 2004) identified 30297 different words and 14011 different lemmatized words based on a subset of about 86 million words of British National Corpus occurring at least 100 times. In addition, Chujo (Chujo 2004) found that to achieve a 95 percent coverage—suggested to be needed for reasonable comprehension—concerning the words of popular junior or senior high school *English-for-second-language* textbooks about 3000–3200 highest-ranking lemmatized words of British National Corpus were needed and respectively about 3800–4100 highest-ranking words to succeed in a proficiency test called Test of English for International Communication (TOEIC).

In the domain of learning English-for-second-language, Hsu (Hsu 2009) reports that intermediate college/university English-for-second-language textbooks typically have a vocabulary level of 4000–4500 most frequent word families of British National Corpus and that 2000 most frequent word families of the British National Corpus correspond to 11941 different words (word types including base forms, inflected forms and derivatives). In addition, Hsu reports that one typical college/university-English-for-second-language textbook can supply a student having a vocabulary size of 2000 word families with 162–2001 new word families (and 49–415 new academic word families based on set of 570 academic word families by Coxhead (Coxhead 2000)), with an estimate that the ratio of word types to word families is in the range from 1.54 to 2.18.

Deborah et al. (Deborah et al. 2004) found out that 2–4 years old children making inquiries about unfamiliar artifacts seemed to be looking for and being most satisfied with explanations that were given in the terms of the object's functions. Willingham and Price (Willingham & Price 2009) mention based on earlier research that a key word method called mnemonics is an effective way to learn unfamiliar low-frequency words by creating a memorable *mental visualization* (Simpson et al. 1987) emphasizing that the student herself should choose the images relating them to previous knowledge (McCarville 1993).

Some estimates about properties of exposure required for learning that have been just discussed are shown in Table 10.18.

Table 10.18. Some estimates about properties of exposure required for learning.

<i>Parameter concerning coverage of comprehension required for learning</i>	<i>Values found in previous research for this parameter</i>
percentage of known words in text required for sufficient comprehension	95 percent (Nation & Waring 1997); 95 percent (Wozniak & Gorzelanczyk 1994); 98 percent (Hu & Nation 2000) 95–98 percent (Laufer & Ravenhorst-Kalakovski 2010) 98–99 percent (Carver 1994)
unique words in a text collection of 5 million words	86741 words ((Hsu 2009) referring to (Carrol et al. 1971))
core vocabulary of English texts	7873 words (Gerlach & Altmann 2013)
size of vocabulary and its coverage of text	107 basic words cover about 50 percent ((Lehr et al. 2004) referring to (Zeno et al. 1995)); <i>based on text collection of 100 million words:</i> 6318 lemmatized words (occurring more than (or at least) 800 times) (Kilgarriff 1997); 14011 lemmatized words (occurring at least 100 times) (Chujo 2004) <i>based on text collection of 5 million words:</i> 2000 words cover about 80 percent ((Hsu 2009) referring to (Carrol et al. 1971)); 5000 words cover about 90 percent ((Hsu 2009) referring to (Carrol et al. 1971)); 12000 words cover about 95 percent ((Hsu 2009) referring to (Carrol et al. 1971)) <i>based on text collection with moderate size:</i> 3000–5000 word families or just 2000–3000 word families can cover 95 percent of suitable texts (Nation & Waring 1997) 4000–5000 words can cover 95 percent and 8000 words can cover 98 percent of text (Laufer & Ravenhorst-Kalakovski 2010) 3000–3200 highest-ranking lemmatized words of British National Corpus can cover 95 percent of high school text book (Chujo 2004); 3800–4100 highest-ranking words of British National Corpus can enable succeeding in proficiency test (Chujo 2004); a text book of college/university-English-for-second-language has a vocabulary level of 4000–4500 most frequent word families of British National Corpus (Hsu 2009) 2000 most frequent word families of British National Corpus correspond to 11941 different words and generally the proportion of word to word families is in range 1.54–2.18 (Hsu 2009) student's earlier vocabulary of 2000 word families can be increased with 162–2001 new word families by a text book of college/university-English-for-second-language (Hsu 2009)

10.4. Distributions of concepts

According to *Zipf's law* (Zipf 1935) pioneered by findings of Jean-Baptiste Estoup (Petruszewycz 1973), in large samples of natural language the frequency of any word $f(z)$ is inversely proportional to its rank z based on the high-frequency list of all words, i.e. $f(z) \sim z^{-\zeta}$ with scaling exponent ζ (Greek alphabet zeta) having value of about 1. When considering word frequency distribution with probability density function $P(f)$ it appears in a form proportional to $f^{-\alpha}$ where the value of α (Greek alphabet alpha) has two variants: for universally shared words with $f > 10^{-5}$ there is $\alpha \approx 1 + 1/\zeta \approx 2$ whereas for significantly less frequently universally used words with $f < 10^{-5}$ there is $\alpha \approx 1.7$ (these values should hold for example in English language but some languages such as Chinese, Russian and Hebrew seem to have lower values) (Petersen et al. 2012). The behavior of Zipf's law has been explained by Simon (Simon 1955) with a model according to which a document is expanded either with new word that has not yet occurred in the document with probability of β (Greek alphabet beta) or with an old

word with probability of $1 - \beta$, and this model is connected to the rank-frequency distribution of Zipf's law with a relation $\alpha = 1 + 1/(1 - \beta)$ (Simkin & Roychowdhury 2011).

In the notation concerning what we have just explained we have tried our best to synchronize usage of Greek letters in notation of (Simkin & Roychowdhury 2011) and (Petersen et al. 2012) so that they could correctly refer to same things without confusion.

According to *Heaps' law* (Heaps 1978), pioneered by Herdan's law (Herdan 1960), the number of distinct words in a document N_w is proportional to N_u^b , where N_u is the total number of words in a document and $b < 1$. When progressively excluding extremely rare words from large document, the value of b increases from 0.5 to 1 and especially when having words with frequencies of at least 1000 the value of b approaches 1 thus following relation $b = 1 / \zeta$ that has been suggested to connect Zipf's law and Heaps' law (Petersen et al. 2012).

It has been shown that the content of the Wikipedia follows approximately Zipf's law so that the exponent of probability density function $\alpha \approx 1.83$ and also Heaps' law so that the number of distinct words $w(n)$ grows sublinearly with n (Serrano et al. 2009). We think that since human communication in various forms of language seems to follow for example Zipf's law and Heaps' law it might be possible that also various forms of visualizations of educational material, possibly relying on exploration in conceptual networks, can have similar kind of naturally emerging models concerning optimally organized distributions and this kind of features could deserve to become exploited in development of new methods to support learning. It has been noted that there is increasing marginal return and decreasing marginal need for the addition of new words to language, and arrival of new words to a language seem to have growth-spurts of about 30–50 years after their introduction in written texts (Petersen et al. 2012).

In an analysis covering million domains having highest traffic of the Web, it was estimated that concerning hierarchical structures following power law distributions in *the Web* the alpha for *in-degree distribution* was 2.3 and the alpha for *out-degree distribution* was 2.4 (Ludueña et al. 2013). In an analysis covering over 400 million Web pages, it was estimated that a mean in-degree was 6.10 and a mean out-degree was 38.11 (Najork et al. 2007). Capocci et al. (Capocci et al. 2006) estimated, with an analysis covering 100 language versions of the Wikipedia, that both in-degree and out-degree distribution of the Wikipedia obey power law with $2 \leq \alpha \leq 2.2$. Zlatic et al. (Zlatic et al. 2006) estimated with ten language versions of *the Wikipedia* that on average the alpha for *in-degree distribution* was 2.18 and for *out-degree distribution* 2.57, whereas for *English version* only the corresponding alpha values were 2.21 (in-degree) and 2.65 (out-degree).

In an analysis containing 650 000 Wikipedia articles having mean length of 2473 characters and median length of 1309 characters, Kams and Koolen (Kamps & Koolen 2009) computed that between Wikipedia articles both mean in-degree and mean out-degree had value 20.63, whereas median in-degree was 4 and median out-degree 12. In addition they found that both in-degree and out-degree of Wikipedia articles are good indicators of relevance of the article and difference between articles serving as hubs

(based on outgoing links) and authorities (based on ingoing links) disappear, and that there was a weak correlation between in-degree and out-degree as well as in-degree and article length whereas a strong correlation between out-degree and article length. It was shown in Wikipedia that distributions of both in-degree and PageRank values, used for evaluating popularity of web sites in network based on model of random walks, follow power laws with same exponent (Volkovich et al. 2007).

It has been shown that so called featured articles of the Wikipedia that have passed a specific evaluation process to meet requirements of high quality have substantially more editors involved than non-featured articles, and articles that have been edited by more editors are generally better than those edited by less editors but addition of editors requiring appropriate coordination techniques (Kittur & Kraut 2008). As already mentioned in Chapter 6 concerning articles that have been labeled in Wikipedia's own review process as "good articles" and "featured articles", Blumenstock (Blumenstock 2008) showed that the *featured articles* can be recognized correctly with the accuracy of 96 percent using a simple heuristic that classifies articles with more than 2000 words as "featured" and articles with fewer than 2000 words as "random", and that Thomas and Sheth (Thomas & Sheth 2007) showed that when comparing labelled *good articles* to other non-stub articles having at least 50 revision milestones they found no statistically significant difference in convergence to a semantically stable state.

On the other hand, Braun and Schmidt (Braun & Schmidt 2007) estimated based on sample of 68854 articles of German Wikipedia the number of words per article and the number of unique internal links per article in respect to four quality classes of article including stub articles, normal articles, labeled "good articles" and labeled "featured articles". They found out that there were for stub articles on average 43 words (median value 4), for normal article on average 1196 words (median value 753), for labeled "good article" on average 5386 words (median value 4580) and for labeled "featured article" on average 6689 words (median value 5952). They also found out that there were for stub articles on average 6 internal links (median value 1), for normal article on average 75 internal links (median value 55), for labeled "good article" on average 212 internal links (median value 170) and for labeled "featured article" on average 240 internal links (median value 213).

From different language versions it was estimated that in the growth of the Wikipedia the relation between the number of directed links L and the number of nodes N (i.e. nodes corresponding to Wikipedia articles) in the Wikipedia obeys approximately $L = N^{1.4}$ (Zlatic et al. 2006). Spinellis and Louridas ((Spinellis & Louridas 2008a); (Spinellis & Louridas 2008b)) found out that in the Wikipedia the ratio between incomplete articles (either stubs or being present only as a link to non-existing entry) and complete articles was about 1.35 in January 2008. They also found that having a reference to a non-existent entry is positively correlated with addition of a new article, and when observed in monthly time windows the article was created most often in the month the first reference was made, and this article was created by another person than the person adding the first reference in 97 percent of cases. With a study covering about 5.7 million article revisions and an approximated number of 51 billion views Priedhorsky et al. (Priedhorsky et al. 2007) estimated that about 5 percent of

article revisions are damaged and a typical view encounters damage with probability of about 0.0037.

Some estimates about properties of distributions of concepts that have been just discussed are shown in Table 10.19.

Table 10.19. Some estimates about properties of distributions of concepts.

<i>Parameter concerning evolution of textual content and linkage</i>	<i>Values found in previous research for this parameter</i>
length of Wikipedia article	2473 characters (mean length) and 1309 characters (median length) (Kamps & Koolen 2009); for stub articles on average 43 words (median value 4) (Braun & Schmidt 2007); for normal article on average 1196 words (median value 753) (Braun & Schmidt 2007); for labeled "good article" on average 5386 words (median value 4580) (Braun & Schmidt 2007); for labeled "featured article" on average 6689 words (median value 5952) (Braun & Schmidt 2007)
probability density function of word frequency distribution P(f) (Zipf's law)	<i>for large texts:</i> proportional to f^{-2} (Petersen et al. 2012) <i>for large texts with rare words:</i> proportional to $f^{-1.7}$ (Petersen et al. 2012) <i>for words in the wikipedia:</i> proportional to $f^{-1.83}$ (Serrano et al. 2009)
number of distinct words w(n) in texts of n words (Heaps' law)	<i>for large texts:</i> proportional to n^1 (Petersen et al. 2012) <i>for large texts with rare words:</i> proportional to $n^{0.5}$ (Petersen et al. 2012) <i>for text in the wikipedia:</i> sublinear growth with n (Serrano et al. 2009)
alpha for power law distribution of in-degree and out-degree	<i>in the Web:</i> 2.3 (in-degree) and 2.4 (out-degree) (Ludueña et al. 2013); <i>in the Wikipedia (100 language versions):</i> between 2 and 2.2 (in-degree) and between 2 and 2.2 (out-degree) (Capocci et al. 2006); <i>in the Wikipedia (10 language versions):</i> 2.18 (in-degree) and 2.57 (out-degree) (Zlatic et al. 2006); <i>in the Wikipedia (English version):</i> 2.21 (in-degree) and 2.65 (out-degree) (Zlatic et al. 2006)
values about in-degree and out-degree	<i>in the Web:</i> 6.10 (mean in-degree) and 38.11 (mean out-degree) (Najork et al. 2007) <i>in the Wikipedia:</i> 20.63 (mean in-degree) and 20.63 (mean out-degree) (Kamps & Koolen 2009); 4 (median in-degree) and 12 (median out-degree) (Kamps & Koolen 2009) for stub articles on average 6 internal links (median value 1) (Braun & Schmidt 2007); for normal article on average 75 internal links (median value 55) (Braun & Schmidt 2007); for labeled "good article" on average 212 internal links (median value 170) (Braun & Schmidt 2007); for labeled "featured article" on average 240 internal links (median value 213) (Braun & Schmidt 2007)
relation between number of directed links L and articles N in the Wikipedia	approximately $L=N^{1.4}$ (Zlatic et al. 2006)
features about creation and revisions of Wikipedia articles	the ratio between incomplete articles and complete articles is about 1.35 (Spinellis & Louridas 2008a); a new article was created by another person than the person adding the first reference in 97 percent of cases and most often in timeframe of one month (Spinellis & Louridas 2008a); about 5 percent of article revisions are damaged and a typical view encounters damage with probability of about 0.0037 (Priedhorsky et al. 2007)

10.5. Tasks for learning with conceptual collections

An approach for building fertile conceptual network for learning is to establish linking based on relatedness of features based on various *human ratings*. In this respect interesting is for example early work of Friendly et al. (Friendly 1982) who defined norms for imagery, concreteness, orthographic variables and grammatical usage for a set of 1080 common words of English belonging to Toronto Word Pool used in learning studies. More recently, in similar fashion for example emotional norms have been defined for a set of 600 words (Syssau & Monnier 2009). Samuels et al. (Samuels et al. 2003) showed experimentally that feedback concerning independent learning had significant positive effect on student achievement. Baker et al. (Baker et al. 1992) mention earlier research (Carey 1978) that has suggested that adoption of vocabulary happens with both a *cursory fast mapping* based on even just one exposure to a word and a *deeper extended mapping* requiring typically multiple exposures to word and that a school-aged child can be concurrently processing even 1600 word mapping at various stages of mapping and if a child learns 8 new words per day most of them are learned only cursorily.

Gardner (Gardner 2008) claims that in children's reading collections there is a great difference in vocabularies of *narrative texts* and *expository texts* and although expository texts have not been considered friendly to incidental word learning from context (Anderson 1996) expository texts are suggested to provide useful conditions for topic-related theme-specific vocabulary recycling especially with a tight theme. According to Gardner, tighter themes in expository texts offered more topic-related vocabulary recycling than looser themes whereas tightness of themes had little or no impact on topic-related vocabulary recycling among narrative texts, and narratives written by the same author offered more topic-related vocabulary recycling than narratives written by multiple authors whereas number of authors had no observable impact on topic-related vocabulary recycling among expository texts. Gentner and Boroditsky (Gentner & Boroditsky 2009) mention based on earlier research that in children's early word learning there is a *noun dominance* in both language production ((Gentner 1982); (Huttenlocher 1974); (Nelson 1973)) and comprehension (Goldin-Meadow et al. 1976) motivated by suggestions that concrete objects and entities are easier to individuate and label than relational constellations and that noun meanings vary crosslinguistically less than verb meanings.

Emotional aspects probably affect cognitive processes and *anxiety* seems to have effect on person's ability to generate analogies that establish mappings between entities. Persons having a state of anxiety (i.e. this term does not refer to trait of anxiety) generated to a given base problem analogies that were mainly close analogies and belonging to one domain whereas persons having non-anxious state generated analogies with remote domains and belonging to two or three domains (Feldman & Kokinov 2009). Findings of Tohill and Holyoak (Tohill & Holyoak 2000) suggest that person having state of anxiety prefer more superficial attributive mapping instead of relational mapping. On the other hand, findings of Feldman et al. (Feldman et al. 2010) suggest that persons having anxious state prefer more relational mapping instead of superficial

mapping and they motivate these findings by mentioning based on previous research that in three attentional neural networks distinguished by Posner et al. (Posner et al 2007) state of anxiety has been shown to enhance working of alerting network and orienting network but not significantly executing network whereas trait of anxiety (i.e. this term does not refer to state of anxiety) did not have effect on alerting network and orienting network but seriously diminished executive control (Pacheco-Unguetti et al. 2010).

Johnson (Johnson 2000) considers vocabulary as an important tool to understand the world and to be understood by others and suggests using *thesaurus* to develop language ability. Johnson mentions influential early work of Roget's thesaurus (Roget 1852) aiming to organize general human knowledge with a hierarchical system containing six main categories defined as abstract relations, space, the material world, the intellect, volition, and sentient and moral powers, that were further divided into 1000 semantic subcategories. Johnson also mentions an illustrated children's thesaurus Words to Use (Drysedale 1974) having six main categories defined as The World We Live In, Living Things, Being Alive, How We View the World, Living Together, and Words for Sentence Building that are divided hierarchically further into subcategories to represent words, and publication A Cluster Approach to Elementary Vocabulary Instruction (Marzano & Marzano 1988) that presents a semantical categorization with a three-level *clustering hierarchy* for 7230 words that are commonly used in elementary school texts so that words in clusters at the lowest level are supposed to have the highest semantic relatedness even if they are not required to be synonyms.

Marzano and Marzano (Marzano & Marzano 1988) explain that their clustering hierarchy is based on about 7000 words they selected from three resources ((Harris & Jacobson 1972); (Carrol et al. 1971); (Dahl 1979)), and which they iteratively categorized following review feedback given by 60 elementary school teachers until teachers identified less than 5 words in 1000 words being miscategorized. The clustering hierarchy contains on the highest level 61 *superclusters* of words and superclusters have together 430 clusters on a lower level and then these clusters have 1500 miniclusters on the lowest level. Listing of clustering hierarchy is supplied with suggestions about at which grade level each word could be introduced to a learner relying on grade levels identified by Harris and Jacobson (Harris & Jacobson 1972) based on analysis of elementary school reading series or alternatively estimates by the list of Thorndike and Lorge (Thorndike & Lorge 1943) that were adjusted based on review feedback from 60 teachers assisting the researchers. Table 10.20 shows topics of all 61 superclusters in decreasing order of the number of words they include.

Table 10.20. A list of topics of all 61 superclusters of clustering hierarchy introduced by Marzano and Marzano (Marzano & Marzano 1988) in decreasing order of the number of words they include.

<i>Name of supercluster of words</i>	<i>Number of words</i>		<i>Name of supercluster of words (continued)</i>	<i>Number of words</i>
1. Occupations	364		32. Shapes/dimensions	90
2. Types of motion	321		33. Destructive/helpful actions	87
3. Size/quantity	310		34. Sports/recreation	80
4. Animals	289		35. Language (names for different aspects of written and oral language)	80
5. Feelings/emotions	282		36. Ownership/possession	68
6. Foods/meals (names for various food types and situations involving eating)	263		37. Disease/health	68
7. Time (names for various points and periods of time and words indicating various time relationships between ideas)	251		38. Light (names for light/darkness and things associated with them)	68
8. Machines/engines/tools	244		39. Causality	59
9. Types of people (names for various types or categories of people that are not job related)	237		40. Weather	55
10. Communication (names for various types of communications and actions involving communications)	235		41. Cleanliness/uncleanliness	53
11. Transportation	205		42. Popularity/knownness	52
12. Mental actions/thinking	193		43. Physical traits of people	51
13. Nonemotional traits (general, nonphysical traits of people)	175		44. Touching/grabbing actions	50
14. Location/direction	172		45. Pronouns (personal, possessive, relative, interrogative, indefinite)	50
15. Literature/writing	171		46. Contractions	49
16. Water/liquids (names for different types of liquids and bodies of water)	164		47. Entertainment/the arts	48
17. Clothing	161		48. Actions involving the legs	46
18. Places where people live/dwell	154		49. Mathematics (names for various branches of mathematics, operations and quantities)	46
19. Noises/sounds	143		50. Auxiliary/helping verbs (forms of to be, modals primary and semiauxiliaries)	46
20. Land/terrain (names for general categories of land or terrain)	142		51. Events (names for general and specific types of events)	44
21. Dwellings/shelters (names for various types of dwellings/places of business)	141		52. Temperature/fire	40
22. Materials (names for materials used to make things)	140		53. Images/perceptions	39
23. The human body	128		54. Life/survival	38
24. Vegetation	116		55. Conformity/complexity	34
25. Groups (general names for groups and organizations)	116		56. Difficulty/danger	30
26. Value/correctness	108		57. Texture/durability	30
27. Similarity/dissimilarity (names indicating how similar or different things are and the sameness or difference between ideas)	108		58. Color	29
28. Money/finance	102		59. Chemicals	28
29. Soil/metal/rock	102		60. Facial expressions/actions	21
30. Rooms/furnishings/parts of dwellings	97		61. Electricity/particles of matter	21
31. Attitudinals (words indicating the speaker/writer's attitude about what is being said or written)	96			
<i>(the listing continues on the fourth column of this table)</i>				

With an aim to emphasize primary components of narrative texts relying on findings of Stein and Glenn (Stein & Glenn 1979) and Whaley (Whaley 1981), 61 superclusters belonging to clustering hierarchy of Marzano and Marzano (Marzano & Marzano 1988) were grouped by Hiebert to form 13 *vocabulary megaclusters* (Hiebert 2011). Table 10.21 shows topics of all 13 vocabulary megaclusters of Hiebert (Hiebert 2011) formed by grouping 61 superclusters of Marzano and Marzano (Marzano & Marzano 1988) and indicates superclusters belonging to each vocabulary megacluster.

Table 10.21. A list showing topics of all 13 vocabulary megaclusters of Hiebert (Hiebert 2011) formed by grouping 61 superclusters of Marzano and Marzano (Marzano & Marzano 1988). The numbers in second column indicate the superclusters numbered in Table 10.20 that belong to each megacluster, some of the superclusters have been excluded (including pronouns, contractions and auxiliary/helpful verbs) and some other superclusters have been renamed or merged, as explained by Hiebert (Hiebert 2011).

We expect that Hiebert means Images/perceptions when referring to Senses/perceptions, Groups when referring to Types of groups, Rooms/furnishing/parts of dwellings when referring to Rooms/furnishing, Disease/health when referring to Health/disease, Foods/meals when referring to Foods and Electricity/particles of matter when referring to Electricity, and Motion when referring to Types of motion (indicated with an asterisk (*) in this table).

Name of vocabulary megacluster	Superclusters belonging to current vocabulary megacluster (numbers refer to Table 10.20)
I. Emotions & attitudes	5, 31
II. Communications	10, 19, 12, 53*, 60
III. Traits of character	13, 43
IV. Social relationships	36, 42, 54, 55
V. Characters	1, 9, 25*
VI. Action & motion	2*, 33, 44, 48
VII. Human body	17, 23, 37
VIII. Features of events/things/people	26, 27, 39, 41, 56
IX. Places/events	18, 21, 30*, 51
X. Physical attributes of things/events/experience	3, 7, 14, 32, 57, 58
XI. Natural environment	4, 6*, 16, 20, 24, 29, 38, 40, 49, 52, 59, 61*
XII. Machines	8, 11, 22
XIII. Social systems	15, 28, 34, 35, 47

10.6. Spacing and repetition patterns to support learning

In the frame of cognitive psychology, it has been suggested that learning can be seen to happen both explicitly and implicitly. In vocabulary learning, *explicit learning* can be considered conscious searching, building and testing of hypothesis and assimilation of rules following explicit instruction by studying decontextualized lexis, using dictionaries and interfering from context, whereas *implicit learning* can be considered automatic abstraction of structural knowledge through instances of experience by engaging students in meaning-focused reading (Hunt & Beglar 2005).

Mazur (Mazur 2003) experimentally found indication that *spacing* benefits abstract learning when task is mastered initially and even if the theoretical explanations for spacing effect are missing lists based on previous research (Dempster 1988) three suggested explanations: voluntary attention hypothesis explaining that individuals choose to pay more attention to spaced than non-spaced (massed) repetitions, encoded variability explaining that if information is presented in different contexts there can be more retrieval routes in memory, and rehearsal hypothesis explaining that the ability to

recall benefits from having rehearsal time immediately after presentation of information.

Vlach and Sandhofer (Vlach & Sandhofer 2012) experimentally showed that by spacing lessons in time promoted children's ability for simple and complex generalization of science concepts that was measured one week after the last lesson. Baumann (Baumann 2005) mentions based on earlier research that, largely agreeing with Mezynski (Mezynski 1983) and Graves (Graves 1986), a meta-analysis of Stahl and Fairbanks (Stahl & Fairbanks 1986) found that reading comprehension was promoted when vocabulary instruction contained deeper processing, multiple encounters and combination of definitional and contextual information whereas comprehension was not enhanced when simply providing definitions, having one or two encounters with words, or using drill-and-practice method exclusively.

Bolger et al. (Bolger et al. 2008) experimentally found that exposure to *variable context* resulted in better learning of abstract meaning than similar exposure to a single context and that definitions conveyed this knowledge more effectively than context alone. Scott and Nagy (Scott & Nagy 1997) found out that students seem to experience fundamental difficulties when trying to use information provided in definitions concerning syntactic or semantic categories of unfamiliar words. Dellarosa and Bourne (Dellarosa & Bourne 1985) provided sentences repeatedly in the same form and in a form that maintained meaning with somewhat different words, and they found out that in a reproduction task learners receiving *varied form* managed better, and similar advantage of diversity was gained when providing sentences to learners by varied speakers. Lehr (Lehr 2004) mentions previous research of Cunningham and Stanovich (Cunningham & Stanovich 1991) that found that the vocabulary knowledge for students in grades 4, 5 and 6 gets significant contribution from *reading volume*.

McKeown and Beck (McKeown & Beck 2011) mention based on earlier work that McKeown et al. (McKeown et al. 1985) compared instruction relying on active processing and practicing of definitions, both with either twelve or four encounters of words, finding that only instruction engaging active processing and twelve encounters showed comprehension effects. Nation (Nation 1999) suggested that about ten repetitions is a desirable number of encounters with a word in reading to ensure learning it. Bloom and Shuell (Bloom & Shuell 1981) mention previous research of Reynolds and Glaser (Reynolds & Glaser 1964) finding that retention of learning material can be improved by spaced review whereas simple repetition has only limited influence on retention. *Repeated retrieval* of information has been shown as a key factor to long-term retention (Karpicke & Roediger III 2007). One of the earliest known studies in this field is work by Ebbinghaus (Ebbinghaus 1885) showing the gradually decreasing recalling rate of nonsense syllables as a function of time. Bahrck et al. (Bahrck et al. 1993) showed that the level of retention could remain same with smaller number of repetitions if the spacing was increased, as was the case with 13 repetitions 56 days apart versus 26 repetitions 14 days apart.

Dempster (Dempster 1988) suggested that spacing effect should be more actively applied in educational practices since it seems to have a lot of unexploited potential and argues that despite many early promising findings there seems to be discontinuities in

research and implementation of its results. Sharifian (Sharifian 2002) mentions previous findings of Dempster (Dempster 1987) showing that when the learners were exposed to 38 uncommon English words accompanied with their definitions, the recall was better if a sequence of 38 words was shown three times thus separating re-exposures with 37 words rather than showing each word three times consecutively.

Kahana and Howard (Kahana & Howard 2005) showed that recall of repeated items was better for spaced lists than massed lists and better for widely spaced repetition than moderately spaced repetitions and they suggest the advantage being motivated by contextual variability enabling increased retrieval cues and associations. In meta-analysis of 317 experiments, Cepeda et al. (Cepeda et al. 2006) concluded that when compared to non-spaced learning, *spaced learning of items* consistently showed benefits regardless of retention interval, and learning benefits increased as time lags increased between learning presentations. In addition they concluded that interstudy intervals that produced maximal retention increased as retention interval increased.

Nation and Wang (Nation & Wang 1999) analyzed series of 42 textbooks called graded readers that aim to gradually expand learner's vocabulary by introducing cumulatively 2410 new words at six consecutive complexity levels. Each book contained 6512–28360 words and text in seven books of each level had new words introduced at current level so that after level 1 it gradually decreases from 9.0 percent (level 2) to 1.9 percent (level 6). At five last levels, each new word introduced at current level represented coverage of text decreasing from 0.031 percent (level 2) to 0.005 percent (level 6). To reach ten repetitions assumed to ensure learning each new word, it was estimated that a learner should read 5–9 books at each level, corresponding to reading at each level a text having a total length ranging from 32258 words (level 2) to 200000 words (level 6). Dividing these values by the number of repetitions (ten), it thus follows that while reading the text, *the number of other words between two encounters* of a same word ranges on average from 3226 words (level 2) to 20000 words (level 6). With an assumption that weakening memory requires next encounter to be spaced at most by a week, a suggestion was then formulated that a learner should read each week at least these same amounts of text ranging from 3226 words per week (level 2) to 20000 words per week (level 6).

Hunt and Beglar (Hunt & Beglar 2005) mention based on earlier research that learning effectiveness benefits from *combined distributed adoption and retrieval* of knowledge at the longest delay that still maintains correct recall (Landauer & Bjork 1978), for example gradually increasing delay for repeated retrieval, with a delay of 30 days suggested to maximize retention ((Bahrick 1984); (Bahrick & Phelps 1987)). It has remained open question whether *gradually expanding spacing* of retrieval can outperform evenly spaced retrieval in learning but it has been suggested that in practice increasing retention intervals is likely to be reinforcing for the learner and can be applied without a need to identify the optimal evenly spaced schedule in advance (Balota et al. 2007).

Based on previous research, Thalheimer (Thalheimer 2006) concludes that successful experiments have had three or more repetitions and that longer spacing of repetition supports longer retention periods. He suggests that an *ideal spacing interval*

should be about equal to retention interval thus corresponding to the time the learner is expected to remember information before it is applied. He suggests that consistent and expanding spacing should be equally fertile if the learning relies on tasks in which learner simply perceives prompted presentation of information or tasks in which retrieval relies on giving feedback about learner responses to prompted cues. However, expanding spacing can outperform consistent spacing if learners do not get feedback on their retrievals. He lists three often suggested reasons for advantage of spaced repetition which include getting memory encoding variability due to varying learning contexts, getting deeper processing in memory than with massed repetition and that identifying failures in retention motivates more intense processing.

Research findings about how *neural activity* proceeds and spreads in living neural systems on cellular level can possibly offer some rough guidelines for defining and adjusting suitable spacing for learning activities in educational work. Signals proceed from one neuron to next neuron through synapses that connect first neuron's axon to next neuron's dendrite. The synapse becomes stimulated as axon side releases serotonin and the dendrite side detects it. When stimulated by serotonin above a threshold, a small voltage potential is created called early *long-term potentiation* (LTP) which can last from one to three hours. An influential early mathematical model explaining initiation and propagation of action potentials in neurons is *Hodgkin-Huxley model* that has given ground for many later adaptations (Hodgkin & Huxley 1952). According to *Hebbian learning theory* associative learning relies on simultaneous activation of neural cells that increases synaptic strengths between them (Doidge 2007). Memory traces are stabilized by synaptic consolidation within minutes to hours of learning and by system consolidation within weeks, months or even years.

In *synaptic consolidation*, it has been considered that synaptic plasticity and synaptic strength are important for memory formation and rely largely on long-term potentiation that is prolonged enhanced signal transmission on cellular level between neurons. This is based on complex chemical chain reactions of stimulating and inhibiting neurotransmitter chemicals and proteins produced by genes activated in the nucleus of the cell ((Lynch 2004); (Whitlock et al. 2006)).

In *system consolidation*, to enable long-term memory formation memories are expected to be stored first in the hippocampal region of brain and then transferred to neo-cortex region or alternatively memories are always stored in neo-cortex region but are bound by hippocampal region (Nadel et al. 2003). So called *standard model* assumes that hippocampal complex works first as an index (H-trace) enabling various parts of memory stored in cortical sites (C-traces) to be reactivated/retrieved together but along time these sites become linked directly and the index becomes recycled. Here the suggested working principle remains same for both episodic and semantic memory. Standard model is challenged by *multiple trace theory* (Nadel & Moscovitch 1997) which assumes that hippocampal constantly represents episodic contextual indexes for cortical sites and since each reactivation/retrieval takes place in different context the traces become updated. Now there is a need to consider episodic and semantic memory separately.

Due to ethical reasons research of processes of human brain has been largely based on animals having neural systems resembling sufficiently human neural systems or by studying human patients having exceptional physiology inherently or due to a trauma. Harvey and Svoboda (Harvey & Svoboda 2007) showed with mice and rats that when a spine of synapse is stimulated to action potential also surrounding spines in distance of 10 micrometers are more sensitive for stimulus for about 10 minutes. Kandel (Kandel 2001) showed that stimulation of synapses of a marine snail can be successfully triggered by 4–5 spaced puffs of serotonin leading to activation of genes establishing *long-term memory*. Fields (Fields 2005) showed that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes. With functional magnetic resonance imaging Tambini et al. (Tambini et al. 2010) showed that during a rest following an associative encoding task the hippocampal-cortical correlations predicted later associative memory.

All these findings seem to indicate that there are fundamental physiological properties of brain that govern under what sequential conditions learning can happen and be efficient. Apparently there is a great variety of individual differences of neurological characteristics but some general guidelines can be suggested based on the findings. Thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures. Marine snail exposed to four brief trains for four days could generate memories that lasted weeks (Kandel 2001).

Some estimates about properties of spacing and repetition patterns to support learning that have been just discussed are shown in Table 10.22.

Table 20.22. Some estimates about properties of spacing and repetition patterns to support learning.

An aspect of spaced learning to be considered	Motivating arguments based on previous research for this aspect
advantage from spaced exposures and multiple exposures	spacing exposures support learning if task mastered initially (Mazur 2003); spacing lessons outperformed non-spacing lessons (Vlach & Sandhofer 2012); multiple exposures outperform one or two exposures ((Baumann 2005) referring to ((Stahl & Fairbanks 1986); (Mezynski 1983); (Graves 1986))); twelve exposures outperform four exposures ((McKeown & Beck 2011) referring to (McKeown et al. 1985)); 10 exposures needed to ensure learning (Nation 1999)
advantage from spaced retentions	repeated retrievals support significantly and repeated exposures only transiently (Reynolds & Glaser 1964); multiple retrievals as a key factor (Karpicke & Roediger III 2007); while maintaining retention level, number of retentions can be decreased if spacing of retentions is increased (Bahrick et al. 1993)
advantage from making spacing wider	3 exposures spaced with 259 seconds outperformed 3 consecutive exposures (Dempster 1987); spaced lists outperformed massed lists and wider spacing outperformed tighter spacing (Kahana & Howard 2005)
some conclusions of meta-analysis of 317 experiments about spaced learning	spacing exposures outperformed non-spaced exposures and wider spacing of exposures outperformed tighter spacing of exposures (Cepeda et al. 2006); spacing of exposures that produced maximal retention increased as spacing of retentions increased (Cepeda et al. 2006)
reaching limits with gradually expanding spacing	exposures should be spaced at most by a week (Nation & Wang 1999); exposures and retention with the longest delay that still maintains recall ((Hunt & Beglar 2005) referring to (Landauer & Bjork 1978)); gradually expanding retention delay until 30-day delay ((Hunt & Beglar 2005) referring to ((Bahrick 1984); (Bahrick & Phelps 1987))); expanding spacing of retention is considered reinforcing and without need to identify optimal evenly spaced intervals in advance (Balota et al. 2007)
tailoring spacing for current situation	3 or more repetitions needed to ensure learning (Thalheimer 2006); longer spacing of exposures supports longer spacing of retention (Thalheimer 2006); spacing of exposures and spacing of retentions should be about equal and match the time required for remembering (Thalheimer 2006); expanding spacing may outperform evenly spaced intervals if learners do not get feedback on their retrievals (Thalheimer 2006)
features of neural systems in learning	stimulus of spine of synapse makes surrounding spines in distance of 10 micrometers more sensitive for about 10 minutes (Harvey & Svoboda 2007) stimulation of synapses can be triggered by 4–5 spaced puffs of serotonin thus activating genes establishing long-term memory (Kandel 2001) at least three action potentials at least 10 minutes apart can activate a gene for long-term memory formation in a synapse and activated gene can produce required proteins for about 30 minutes (Fields 2005). marine snail exposed to four brief trains for four days could generate memories that lasted weeks (Kandel 2001)

10.7. Manageable amounts of information in learning

Empirical findings show that increasing physiological and mental arousal is positively correlated with person's increasing performance up to somewhat optimal peak level but if physiological and mental arousal still further increase the performance declines and this relationship referred to as *Yerkes-Dodson law* has been connected to effects of stress hormones ((Yerkes & Dodson 1908); (Diamond, D. et al. 2007)).

To better understand cognitive processes of students belonging to any age, useful insight can be gained by analyzing developments of *cognitive processes of infants* who

are still in early stages of learning. Wojcik (Wojcik 2013) mentions based on previous research that maximum *time of remembering* for infants who are 2–18 months old increases monotonically so that 2-month-olds can retain a memory after one day, 3-month-olds after one week, 6-month-old after two weeks, 9-month-olds after six weeks, 12-month-olds after eight weeks, 15-month-olds after ten weeks and 18-month-olds after thirteen weeks ((Hartshorn et al. 1998); (Vander Linde et al. 1985); (Greco et al. 1990); (Hill et al. 1988); (Hartshorn & Rovee-Collier 1997)).

In addition, Wojcik (Wojcik 2013) mentions based on previous research that older infants need shorter *exposure times* to learn given stimuli than younger infants so that 2-month-olds need 3–6 minutes of exposure, 3-month-olds need 2–3 minutes exposure and 6-month-olds need 1 minute exposure ((Greco et al. 1986); (Greco et al. 1990); (Hill et al. 1988)). Furthermore, Wojcik (Wojcik 2013) mentions based on previous research that for infants the maximum *retention time* is the same for both reactivated memory and original memory ((Rovee-Collier et al. 1980); (Hildreth & Rovee-Collier 2002); (Hildreth et al. 2003)), and 2-month-olds can after two training session separated by one day followed by six spaced reminder sessions 3 weeks apart still show signs of retention (Rovee-Collier et al. 1999).

Based on over 32000 hours of data from 2682 recordings of LENA Natural Language study carried out with 329 participants in first phase and 80 participants in second phase produced measures about *language development of infants*. This study showed that on average children in ages of 2–30 months heard from all adults about 12815 words per day and this consisted of about 3184 words per day coming from male adult and about 9631 words per day coming from female adult and female child hears about 5.8 percent more words than male child, and for a typical family with a 24-month-old child there were on average 520 *conversational turns* per day (Gilkerson & Richards 2009). Based on recorded speech samples of 396 persons in age range of 17–29 years, it was estimated that men spoke 15669 words and women 16215 words per day (Mehl et al. 2007).

In addition LENA Natural Language study (Gilkerson & Richards 2009) showed that when children grow older those children that have more talkative parents generate higher number of daily child *vocalizations* than those children that have less talkative parents. This difference in average daily child vocalizations for children having parents that belong to the lowest 20th percentile in contrast with the highest 20th percentile in respect to adult word count seems to define following estimated value ranges that we visually interpreted from a graph from LENA Natural Language study so that lower end of range represent having parents that belong to the lowest 20th percentile and higher end of range represents having parents that belong to the highest 20th percentile in respect to adult word count: 2-month-olds generate about 550 daily child vocalizations (about same value for children of both talkative and untalkative parents), 6-month-olds about 800–1000 daily child vocalizations, 12-month-olds about 1000–1500 daily child vocalizations, 18-month-olds about 1200–1800 daily child vocalizations, 24-month-olds about 1300–2200 daily child vocalizations, 36-month-olds about 1600–2700 daily child vocalizations and 48-month-olds about 1700–2700 daily child vocalizations (Gilkerson & Richards 2009).

Juster et al. (Juster, F. et al. 2004) measured *time use for students* of ages of 6–17 years living in a family having computer with internet measured in years 2002–2003 based on data about 2908 children. Time use in school per week was 33 h 54 min for 6–8-year-olds, 32 h 44 min for 9–11-year-olds, 33 h 15 min for 12–14-year-olds and 30 h 21 min for 15–17-year-olds (Juster, F. et al. 2004). Time use in studying (excluding time used in school) per week was 2 h 26 min for 6–8-year-olds, 3 h 31 min for 9–11-year-olds, 5 h 3 min for 12–14-year-olds and 5 h 20 min for 15–17-year-olds (Juster, F. et al. 2004). Time use in reading per week was 1 h 28 min for 6–8-year-olds, 1 h 42 min for 9–11-year-olds, 1 h 42 min for 12–14-year-olds and 0 h 58 min for 15–17-year-olds (Juster, F. et al. 2004). Time use in being read to per week was 0 h 12 min for 6–8-year-olds, 0 h 6 min for 9–11-year-olds, 0 h 3 min for 12–14-year-olds and 0 h 0 min for 15–17-year-olds (Juster, F. et al. 2004). Time use in computer activities per week was 1 h 8 min for 6–8-year-olds, 1 h 41 min for 9–11-year-olds, 4 h 5 min for 12–14-year-olds and 6 h 6 min for 15–17-year-olds (Juster et al. 2004).

It has been estimated that time required to adopt professional *proficiency in a foreign language* by a native English speaker ranges from 23–24 weeks or 575–600 class hours (for languages that are closely related to English, for example French) to 88 weeks or 2200 class hours (for languages which are exceptionally difficult, for example Arabic) (Sanatullova-Allison 2009). Related to just described estimates please note that Subchapter 11.2 discusses about requirements suggested for reaching six progressive language ability levels of Common European Framework of Reference.

We think that above mentioned results of previous research motivate creating such educational content and its adaptive representation techniques that could enable a learner to become optimally sequentially exposed to new knowledge and its retention with sufficient spacing and repetition. The optimal timing schemes could be experimentally tailored for each learner to address her personal characteristics, age and level of knowledge as well as for each learning topic. Pavlik and Anderson (Pavlik & Anderson 2008) showed that an algorithm tailored to dynamically increase and decrease temporal spacing of items provided an optimized condition that improved recall and recall latency when compared to other conditions, thus aiming to both increasing long-term recall and minimizing failure-related time cost of practice. Mettler et al. (Mettler et al. 2011) suggested that repetition intervals should be defined as an inverse function of response time and an experimental group learning basic multiplication facts with this method outperformed a group attending traditional instruction.

Some estimates about properties of manageable amount of information in learning that have been just discussed are shown in Table 10.23.

Table 20.23. Some estimates about properties of manageable amounts of information in learning.

<i>An aspect of manageable amount of information in learning to be considered</i>	<i>Values found in previous research concerning this aspect</i>
possible duration of time to still retain a memory for infants	for 2-month-olds after 1 day ((Wojcik 2013) referring to (Vander Linde et al. 1985)); for 3-month-olds after 1 week ((Wojcik 2013) referring to (Greco et al. 1990)); for 6-month-olds after 2 weeks ((Wojcik 2013) referring to ((Hill et al. 1988); (Hartshorn & Rovee-Collier 1997)); for 9-month-olds after 6 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 12-month-olds after 8 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 15-month-olds after 10 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 18-month-olds after 13 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998))
exposure of stimuli needed for learning for infants	2-month-olds need 3–6 minutes ((Wojcik 2013) referring to (Greco et al. 1986)); 3-month-olds need 2–3 minutes ((Wojcik 2013) referring to (Greco et al. 1990)); 6-month-olds need 1 minute ((Wojcik 2013) referring to (Hill et al. 1988))
words children in ages of 2–30 months hear from adults	12815 words per day from all adults (Gilkerson & Richards 2009); 3184 words per day from male adult (Gilkerson & Richards 2009); 9631 words per day from female adult (Gilkerson & Richards 2009); 520 conversational turns per day for 24-month-old child in a typical family (Gilkerson & Richards 2009)
range of values of daily child vocalizations for children so that lower end of range represent having parents that belong to lowest 20th percentile and higher end of range represents having parents that belong to the highest 20th percentile in respect to adult word count	for 2-month-olds about 550 daily child vocalizations (about same value for children of both talkative and untalkative parents) (Gilkerson & Richards 2009); 6-month-olds about 800–1000 daily child vocalizations (Gilkerson & Richards 2009); 12-month-olds about 1000–1500 daily child vocalizations (Gilkerson & Richards 2009); 18-month-olds about 1200–1800 daily child vocalizations (Gilkerson & Richards 2009); 24-month-olds about 1300–2200 daily child vocalizations (Gilkerson & Richards 2009); 36-month-olds about 1600–2700 daily child vocalizations (Gilkerson & Richards 2009); and 48-month-olds about 1700–2700 daily child vocalizations (Gilkerson & Richards 2009)
spoken words for persons in age range of 17–29 years	15669 words per day (men) (Mehl et al. 2007); 16215 words per day (women) (Mehl et al. 2007)
time used in school per week for students of ages of 6–17 years living in a family having computer with internet	33 h 54 min (6–8-year-olds) (Juster et al. 2004); 32 h 44 min (9–11-year-olds) (Juster et al. 2004); 33 h 15 min (12–14-year-olds) (Juster et al. 2004); 30 h 21 min (15–17-year-olds) (Juster et al. 2004)
time used in studying (excluding time used in school) per week for students of ages of 6–17 years living in a family having computer with internet	2 h 26 min (6–8-year-olds) (Juster et al. 2004); 3 h 31 min (9–11-year-olds) (Juster et al. 2004); 5 h 3 min (12–14-year-olds) (Juster et al. 2004); 5 h 20 min (15–17-year-olds) (Juster et al. 2004)
time used in reading per week for students of ages of 6–17 years living in a family having computer with internet	1 h 28 min (6–8-year-olds) (Juster et al. 2004); 1 h 42 min (9–11-year-olds) (Juster et al. 2004); 1 h 42 min (12–14-year-olds) (Juster et al. 2004); 0 h 58 min (15–17-year-olds) (Juster et al. 2004)
time used in being read to per week for students of ages of 6–17 years living in a family having computer with internet	0 h 12 min (6–8-year-olds) (Juster et al. 2004); 0 h 6 min (9–11-year-olds) (Juster et al. 2004); 0 h 3 min (12–14-year-olds) (Juster et al. 2004); 0 h 0 min (15–17-year-olds) (Juster et al. 2004)
time used in computer activities per week for students of ages of 6–17 years living in a family having computer with internet	1 h 8 min (6–8-year-olds) (Juster et al. 2004); 1 h 41 min (9–11-year-olds) (Juster et al. 2004); 4 h 5 min (12–14-year-olds) (Juster et al. 2004); 6 h 6 min (15–17-year-olds) (Juster et al. 2004)
time required to adopt professional proficiency in a foreign language by a native English speaker	ranging from 23–24 weeks or 575–600 class hours (language closely related to English, for example French) to 88 weeks or 2200 class hours (language which is exceptionally difficult, for example Arabic) (Sanatullova-Allison 2009)

10.8. Supporting successful reading

It has been shown that with a 140-item form of *vocabulary size test*, each item containing a multiple-choice question with four alternative definitions to choose from for a given concept, is capable of providing reliable and valid measure of vocabulary size of student ((Nation & Beglar 2007); (Beglar 2010)). We suggest that similarly a sufficiently long and diverse exploration path traversed in a hyperlink network representing conceptual relationships of a vocabulary could possibly relatively reliably measure the vocabulary size of student and also other characteristics defining the learner's abilities and success of learning. We think that while exploring in hyperlink network when a learner is required to select which of alternative hyperlinks to traverse next these selections cumulatively correspond to answering a series of multiple-choice questions. Based on a review of research about independent reading, Paul (Paul 2004) concludes that before transition at around third or fourth grade from "learning to read" to "reading to learn" a goal of 85 percent correct in a *comprehension quiz* is a reasonable goal for students but at later grades the greatest gains in reading achievement happened with about 93–96 percent correct in quizzes. Paul recommends that students should read books that introduce new vocabulary but not excessively which can bring frustration.

When learning relies on exploration in hyperlink network we think that finding the most educationally rewarding path can be supported also with solutions identified for *optimal stopping procedure* (i.e. marriage problem, secretary problem or best choice problem, also concerning Odds algorithm) and related to this it has been found that brain regions identified to take part in evidence integration and reward representation encode threshold crossings which trigger decisions about committing to choice (Costa & Averbeck 2013). Therefore while deciding among all n outgoing hyperlinks which outgoing hyperlink to traverse next from current concept and if learner must select or reject each of alternative outgoing hyperlinks one by one, we suggest that optimal strategy is to first directly reject about n/e of alternatives (here e denotes Napier's constant) and then select the next alternative that is better than all alternatives so far (or to select the last alternative) thus leading to that the probability of selecting the best alternative to converge towards $1/e$ (≈ 0.3679) when n increases, as motivated by results of Bruss (Bruss 1984).

Soureshjani and Naseri (Soureshjani & Naseri 2011) mention based on previous meta-analysis (Swanburn & de Glopper 1999) that readers can achieve partial understanding of about 15 percent of unfamiliar words that they encounter in reading. Nagy et al. (Nagy et al. 1987) mention earlier results that students managed to *learn a word from context* with probability in the range of 15–22 percent when multiple-choice test was arranged within 15 minutes after reading a given text (Nagy et al. 1985). When Nagy et al. (Nagy et al. 1987) carried out an another similar experiment the probability of learning a word from context was 5 percent when multiple-choice test was arranged 6 days after reading a given text showing additionally that students who had read a given

text knew 3.3 percent more of its difficult words than students who had not read that text.

Anderson et al. (Anderson et al. 1988) identified that the *amount of reading* of students of 5th grade was positively correlated with their reading achievement, and students achieving 98th percentile in reading test scores read 90.7 minutes per day and 4733000 words per year whereas students achieving 50th percentile read 12.9 minutes per day and 601000 words per year. Wu and Samuels (Wu & Samuels 2004) showed experimentally that *time spent for independent reading* has a positive effect on reading achievement so that for low ability group a 15 minutes silent reading session appeared better for improving reading speed and comprehension whereas a 40 minutes session appeared better for improving word recognition, and for high ability group a 40 minutes session appeared better for all these skills.

McDaniel and Butler (McDaniel & Butler 2010) mention based on previous research that introducing so called *desirable difficulties* to the learner can have an important role in enhance learning (Bjork 1994). Inspiration for developing educational technology can be gained by taking a look at evolution of *readability research* that can be characterized by introduction of statistical analysis about text, generation of vocabulary frequency lists and definition of readability formulas based on semantic and syntactic measures to match reader with suitable text (DuBay 2004). Contributions coming from linguistics and cognitive psychology have increased complexity of models to consider motivation and background knowledge of reader that can affect readability.

Lewandowski et al. (Lewandowski et al. 2003) estimate that the *reading rate* for population in general is around an approximate value of 200 words per minute. For sufficient comprehension reading rate of at least about 200 words per minute (Anderson 1999) and average sentence length below 20 words (DuBay 2004) was suggested, thus resulting at least 10 sentences per minute. Based on *Flesch reading ease test* that considers those texts more difficult that have higher number of words per sentence and syllables per word, Lucassen et al. (Lucassen et al. 2012) tried to estimate the readability of articles of the Wikipedia. When evaluating all available articles of the English Wikipedia the readability turned out to be poor due to 73.5 percent of the articles having measures below desirable Standard score (60) whereas with articles of Simple English Wikipedia 42.3 percent remained under Standard score although still 94.7 percent remaining under Easy score (80).

Some estimates about properties of supporting successful reading that have been just discussed are shown in Table 10.24.

Table 10.24. Some estimates about properties of supporting successful reading.

<i>An aspect of supporting successful reading to be considered</i>	<i>Values found in previous research concerning this aspect</i>
some requirements for reliable and valid vocabulary size test based on multiple-choice questions:	140 multiple-choice questions each having 4 alternative definitions (Nation & Beglar 2007)
an optimal strategy for optimal stopping procedure for selecting among n alternatives that must be selected or rejected one by one	first directly rejecting about n/e of alternatives (here e denotes Napier's constant) and then selecting the next alternative that is better than all alternatives so far (or selecting the last alternative) thus leading to that the probability of selecting the best alternative to converges towards $1/e$ (≈ 0.3679) when n increases (Bruss 1984)
coverage needed with comprehension quizzes for successful reading achievement	85 percent correct (until 3rd or 4 th grade) (Paul 2004); 93–96 percent (from 3rd or 4th grade) (Paul 2004)
probability of learning a word from context	about 15 percent (partial understanding) ((Soureshjani & Naseri 2011) referring to (Swanburn & de Glopper 1999)); 15–22 percent (if multiple-choice test within 15 minutes) (Nagy et al. 1985); 5 percent (if multiple-choice test after 6 days) (Nagy et al. 1987)
increase in level of knowing difficult words in a text after reading that text:	3.3 percent more (Nagy et al. 1987)
reading performance of student measured in time used and amount of text read	a student with average score in reading test: reads 12.9 minutes per day or 601000 words per year (Anderson et al. 1988); a student with excellent score in reading test: reads 90.7 minutes per day or 4733000 words per year (Anderson et al. 1988)
time spent for independent reading affecting reading achievement	<i>for low ability group:</i> a 15 minutes silent reading session was better for improving reading speed and comprehension whereas a 40 minutes session better for improving word recognition (Wu & Samuels 2004) <i>for high ability group:</i> a 40 minutes session was better than 15 minutes session for improving reading speed and comprehension and improving word recognition (Wu & Samuels 2004).
reading speed and comprehension:	<i>for population in general:</i> about 200 words per minute. (Lewandowski et al. 2003) <i>for sufficient comprehension:</i> at least about 200 words per minute (Anderson 1999) average sentence length below 20 words (DuBay 2004) thus resulting at least 10 sentences per minute
readability of text in the Wikipedia (Flesch reading ease test)	<i>English Wikipedia:</i> 73.5 percent below desirable Standard score (60) (Lucassen et al. 2012) <i>Simple English Wikipedia:</i> 42.3 percent under Standard score (60), still 94.7 percent under Easy score (80) (Lucassen et al. 2012)

10.9. Properties of networks that affect representing conceptual relationships

Small-world networks are networks that have a small average distance (or diameter) between nodes d so that for N nodes in network each having z neighbors the average distance can be estimated with formula $d = \log N / \log z$ (Newman 2000). *Scale-free networks* are networks whose nodes N have a probability of having k connections to other nodes that is proportional to $ck^{-\lambda}$ with parameters c and λ (Cohen & Havlin 2003). When parameter λ in range $2 < \lambda < 3$, average distance between nodes d in scale-free networks have been shown to be especially small following relation $d \sim \ln \ln N$ (Cohen & Havlin 2003).

Small-world networks have been considered as flexible and efficient structures that can be found inherently in many natural and sociological processes and it has been proposed that they have an important role for organizing and processing knowledge in biological neural networks ((Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010)). Bullmore and Sporns (Bullmore & Sporns 2009) report that some studies with high spatial resolution have indicated that organization of functional brain networks holds scale-free properties ((Eguíluz et al. 2005); (Van den Heuvel 2008)) whereas some other studies indicated instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Small-world networks have been identified emerging in both social networks (Uzzi et al. 2007), wikis (Mehler 2006) and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009). The Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)) and represents a hierarchical structure following so called power law, and the distribution of category sizes s has been estimated to be proportional to $s^{-\lambda}$ with λ having value of about 2.2 and a similar kind of power law decay emerged in link-based cluster size distribution (Capocci et al. 2008). When analysing the linking between articles, the hyperlink network of the Wikipedia has been found to be scale-free concerning ingoing links, outgoing links and broken links, and article sizes were lognormal distributed having linear growing median (Voß 2005). To explain evolution of scale-free network structures Barabási & Albert (Barabási & Albert 1999) have suggested a model making new vertices attached preferentially to already well connected nodes.

It has been found that many features in the Wikipedia follow the *power law distribution*. These features include the number of distinct authors per Wikipedia article for articles having 5–40 authors ($\gamma \approx 2.7$), number of distinct articles edited per author ($\gamma \approx 1.5$), number of edits per author ($\gamma \approx 0.5$) and number of wanted articles per number of broken links pointing to them ($\gamma \approx 3$) (Voß 2005). Thus according to Voß the distribution of authoring of the Wikipedia seems to have accordance with *Lotka's law* which has been earlier identified in patterns of scientific publishing stating that the number of authors creating n contributions is approximately $1/n^a$ of number of those authors that make one contribution, with parameter a typically having value close 2 (Lotka 1926).

Small-world networks have been considered as an interesting form of networks due to their flexible and efficient way to represent structure and growth of connectivity of various natural processes ((Watts & Strogatz 1998); (Kleinberg 2000); (Newman 2003)). Also when trying to find consensus of agents and address synchronization problems in a network the small-world network has been considered to offer an especially efficient connectivity (Gu et al. 2010). Even when having very little knowledge of a given small-world network it has been shown that it is possible to route or navigate in it efficiently ((Kleinberg 2000); (Franceschetti & Meester 2006); (Sandberg 2008)).

Due to just mentioned scale-free small-world properties of *the Wikipedia* we think that the Wikipedia's hyperlink network can inherently provide relatively optimal structure for representation, management and exploration of *educational knowledge*.

Despite mixed acceptance from educators (Watson & Harper 2008), the *coverage* and *quality* of the Wikipedia is said to meet the level of respected encyclopedias (Giles 2005) and median survival time for vandalism edits is 11 minutes (Kittur et al. 2007a). We think that a large part of curriculum has already been iteratively elaborated in the articles of Wikipedia. Wikipedia has many collaboratively agreed structural characteristics that intuitively support a learner to find personalized learning material at an appropriate level of complexity. We consider that the Wikipedia can adaptively support personalized learning of concepts and their relations. Each article defines a concept denoted by its title and its hyperlinks define relationships to other concepts.

According to experiment reported by Dolan (Dolan 2011) based on full hyperlink network of Wikipedia version dating from 3 of March 2008, it takes *on average 4.573 traversals of hyperlinks* to get from any Wikipedia article to any other Wikipedia article. Dolan reports that at that time 3 March 2008 the Wikipedia contained 2301486 articles with 55550003 hyperlinks between them and furthermore there was a subentity of 2111480 articles which enabled traversing hyperlink chains between any articles belonging to this subentity. Dolan also reports that the article enabling the shortest connectivity to all other articles, so called departure center, was article named “2007” (average distance to other articles 3.45 hyperlinks) followed by article “Deaths in 2004” and article “2006”. Or, if excluding lists, years or days of year, the departure center was article “United Kingdom” (average distance to other articles 3.67 hyperlinks), followed by “Billie Jean King” (3.68 hyperlinks) and “United States” (3.69 hyperlinks).

In social networks of people, estimates have been made about the average length of the *shortest chains of relationships* connecting any two persons through intermediate persons. Famous result gained in 1960s by asking 296 arbitrarily selected individuals to send mail to a given target person through personal relationship chains showed that average distance was in the range *between 4.6 and 6.1 relationship steps* (Travers and Milgram 1969). Later resembling experiments have given support for an average distance in an approximately similar kind of range for other social networks. In May 2011, analysis of 721 million active users of Facebook social networking service (over 10 percent of the global population) and 68.7 billion links established between them showed that the average distance between any two users is about *4.74 relationship steps*, the value has had recently a decreasing trend but was apparently stabilizing (Backstrom et al. 2011). Furthermore, a related analysis showed that an active Facebook user has on average 190 direct relationships with other persons and a user having a median value of 100 friends has 27500 unique friend-of-friends (Ugander et al. 2011).

Forming a brief summary about evolution of network models that have been developed to manage network simulations, Prettejohn et al. (Prettejohn et al. 2011) mention *random network models of Erdős and Rényi* ((Erdős & Rényi 1959); (Erdős & Rényi 1960)) enabling shorter average paths than ordered networks but missing small-world and scale-free properties, *model of Watts and Strogatz* (Watts & Strogatz 1998) offering small-world properties but missing scale-free properties, *model of Barabási and Albert* (Barabási & Albert 1999) offering scale-free properties but missing small-world properties, and *model of Klemm and Eguílez* (Klemm & Eguílez 2002) offering both small-world and scale-free properties. Bollobás and Chung (Bollobás & Chung

1988) determined that a graph consisting of an n -cycle and random matching has a diameter of about $\log_2 n$.

A network can be modeled by nodes located on a two-dimensional grid and expecting that each node has links to all nodes located within a certain amount of steps on grid. To enable *fast decentralized search* in a large network it is efficient to have such long-range link structure that a node v links to another node w with a *probability decaying along distance* so that probability is proportional to $d(v,w)^{-q}$ in which $d(v,w)$ denotes the distance of v and w as steps between them on a grid containing the nodes and q has value close to 2. Besides giving a more detailed proof for the just mentioned grid modeling approach, Easley and Kleinberg (Easley & Kleinberg 2010) motivate this by an idea that in an area ranging from distance d to $2d$ the number of nodes on grid is proportional to d^2 and probability of linking to each node is proportional to d^{-2} and thus probability of random linking to some node is – due to d^2 and d^{-2} canceling out – approximately independent of value of d . Thus $q=2$ seems to ensure a uniform distribution of long-range links over all different scales of hierarchical resolution.

In a network when using a routing algorithm based on only local information, the *number of nodes visited* before reaching the target node is minimized when probability of having a link between two nodes decays with the square of their distance and only with this condition it is possible to reach the target in logarithmic number of steps (Franceschetti & Meester 2006). In networks having *non-uniformly spaced nodes*, linking probabilities can be usefully determined so that a node v links to another node w based on $\text{rank}(w)$ that depicts w 's ranking position among all possible nodes linkable from v . With *uniformly spaced nodes*, when node w is at distance d from node v , node w is on circumference of a disc that contains, in approximation, d^2 nodes more closely positioned to v than w is, and thus $\text{rank}(w)$ can be approximated with d^2 . Therefore linking among uniformly spaced nodes from node v to node w with probability proportional to d^{-2} can be considered to suggest a generalization even for non-uniformly spaced nodes so that it resembles linking with probability $\text{rank}(w)^{-1}$ thus meaning *probability decaying along ranking position* (Easley & Kleinberg 2010).

Liben-Nowell et al. (Liben-Nowell et al. 2005) showed that efficient decentralized search is enabled in social networks when relying on *rank based friendship* in which the probability of person x having a person y as a friend is inversely proportional to the number of other persons being more closely positioned to x than y is. Adamic and Adar (Adamic & Adar 2005) found out in analysis of *communicational social network* of an organization that the probability of linking between individuals as a function of the size g of the smallest organizational group into which both individuals belong to was proportional to $g^{-3/4}$.

Simsek and Jensen (Simsek & Jensen 2005) proposed with an empirical success an algorithm for making decentralized search in networks with a method that combines decision based on degree structure of neighboring nodes and based on how similar the neighboring nodes are to the target node in respect to attribute values. In this algorithm from node u the next step is taken to neighboring node v that maximizes *probability of direct link* to target node t . This relies on probability p_v that a particular one of

friendships of node v will connect to target node t and thus formula $1 - (1 - p_v)^{\text{delta}_v}$ gives the probability that one of the delta_v friendships of v connect v to t .

Rodero-Merino et al. (Rodero-Merino et al. 2010) studied experimentally *random walks in one-hop replication networks* that have a property that every node knows the identity or resources of its neighbors and thus can reply to queries on their behalf. We interpreted some properties of random walks based on figures 7, 9 and 12 shown in their article (Rodero-Merino et al. 2010). In a random walk in a network the *probability of revisiting a node* increases as the number of hops increase and this effect is stronger in small-world network than in a random network. The probability of revisiting a node in a small-world network decreases when the average degree of network increases or when the number of nodes in network increases. In a small-world network containing 50000 nodes a random walk traversing 2000 hops managed to visit about 1600 nodes (about 3 percent) of the network when having an average degree of 10, and approximately the same result was gained when having an average degree of 30. Similarly, in a small-world network containing 50000 nodes a random walk traversing 10000 hops managed to visit about 7500 nodes (about 15 percent) of the network when having an average degree of 10 and about 8100 nodes (about 16 percent) when having an average degree of 30.

Rodero-Merino et al. (Rodero-Merino et al. 2010) showed experimentally that *coverage of a random walk* in small-world network grows faster when the average degree of network is higher and also that an *average search length* grows linearly with the network size and the bigger the average degree the shortest the searches are. In this context covered nodes include both visited nodes and their neighbors that are not required to be visited separately. In a small-world network containing 100000 nodes a random walk traversing 2000 hops managed to cover about 3500 nodes (about 3.5 percent) of the network having an average degree of 10 and to cover about 67000 nodes (about 67 percent) of the network having an average degree of 30. In a small-world network containing 10000 nodes an average search length was about 950 hops when having an average degree of 10 and an average search length was about 200 hops when having an average degree of 30. In a small-world network containing 100000 nodes an average search length was about 9500 hops when having an average degree of 10 and was about 2000 hops when having an average degree of 30. Random walks designed to avoid previous node and thus to decrease revisiting effect offered only a small increase in number of covered nodes in small-world network.

Some estimates about properties of networks affecting representing conceptual relationships that have been just discussed are shown in Table 10.25.

Table 10.25 part 1 of 2 (starts here and continues on next page). Properties of networks affecting representing conceptual relationships.

<i>An aspect of networks affecting representing conceptual relationships to be considered</i>	<i>Values found in previous research concerning this aspect</i>
<p>some characteristics shaping evolution of the Wikipedia and related networks</p>	<p><i>small-world networks</i> for N nodes in network each having z neighbors the average distance can be estimated with $d = \log N / \log z$ (Newman 2000); the Wikipedia is shown to be small-world network ((Ingawale et al. 2009); (Zesch & Gurevych 2007); (Masucci et al. 2011))</p> <p><i>scale-free networks</i> node's probability of having k connections $ck^{-\lambda}$ (Cohen & Havlin 2003); the average distance between nodes (if $2 < \lambda < 3$) proportional to $\ln \ln N$ (Cohen & Havlin 2003) the Wikipedia is shown to be scale-free network ((Zesch & Gurevych 2007); (Masucci et al. 2011); (Voß 2005))</p> <p><i>in the Wikipedia</i> distribution of category sizes proportional to $s^{-2.2}$ (Capocci et al. 2008); similar kind of decay for link-based cluster size distribution (Capocci et al. 2008); scale-free concerning: ingoing links, outgoing links, broken links (Voß 2005); article sizes lognormal distributed with linear growing median (Voß 2005); power law is found concerning: number of distinct authors per article when 5–40 authors ($\gamma \approx 2.7$) (Voß 2005), number of distinct articles edited per author ($\gamma \approx 1.5$) (Voß 2005), number of edits per author ($\gamma \approx 0.5$) (Voß 2005) and number of wanted articles per number of broken links pointing to them ($\gamma \approx 3$) (Voß 2005) the number of authors creating n contributions is approximately $1/n^a$ of number of those authors that make one contribution, with parameter a having value about 2 (Lotka's law) (Voß 2005) median survival time for vandalism in the Wikipedia is 11 minutes (Kittur et al. 2007a)</p>
<p>some estimates for shortest connectivity in socially constructed networks</p>	<p><i>in the Wikipedia</i> (as of 3 March 2008) 2301486 articles with 55550003 hyperlinks between them (Dolan 2011); (sub-entity of 2111480 articles enabled traversing hyperlink chains between any articles belonging to this entity) (Dolan 2011); on average 4.573 traversals of hyperlinks to get from any article to any other article (Dolan 2011); departure center enabling the shortest connectivity to all other articles was article "2007" (average distance to other articles 3.45 hyperlinks) (Dolan 2011); an alternative departure center, if excluding lists, years or days of year, enabling the shortest connectivity to all other articles was article "United Kingdom" (average distance to other articles 3.67 hyperlinks) (Dolan 2011)</p> <p><i>in mailing experiment in USA</i> with 296 persons the number of steps connecting two persons in range 4.6–6.1 (Travers & Milgram 1969);</p> <p><i>in Facebook social network</i> with 721 million users and 68.7 billion links between them the number of steps between two users 4.74 (Backstrom et al. 2011)</p> <p>a Facebook user has on average 190 direct relationships and a Facebook user having median value of 100 friends has 27500 unique friends-of-friends (Ugander et al. 2011)</p>

Table 10.25 part 2 of 2 (started on previous page and continues here). Properties of networks affecting representing conceptual relationships.

An aspect of networks affecting representing conceptual relationships to be considered	Values found in previous research concerning this aspect
<p>some estimates for modeling linkage in small-world networks</p>	<p>a graph consisting of an n-cycle and random matching has diameter about $\log_2 n$ (Bollobás & Chung 1988)</p> <p>to enable fast decentralized search in a large network a link from node v to node w is suggested with a probability proportional close to d^{-2} in which d denotes steps between them (Easley & Kleinberg 2010)</p> <p>in routing based on only local information, the number of nodes visited before reaching the target node is minimized when probability for a link between two nodes decays with the square of their distance and only then the target can be reached in logarithmic number of steps (Franceschetti & Meester 2006)</p> <p>linking among uniformly spaced nodes from node v to node w with probability proportional to d^{-2} can be considered to suggest a generalization even for non-uniformly spaced nodes that it resembles linking with probability $\text{rank}(w)^{-1}$ where $\text{rank}(w)$ depicts w's ranking position among all possible nodes linkable from v (Easley & Kleinberg 2010)</p> <p>to enable efficient decentralized search in social networks (relying on rank based friendship) the probability of person x having a person y as a friend is inversely proportional to the number of other persons being more closely positioned to x than y is (Liben-Nowell et al. 2005)</p> <p>the probability of linking between individuals as a function of the size g of the smallest organizational group into which both individuals belong to is proportional to $g^{-3/4}$ (Adamic & Adar 2005)</p> <p>decentralized search in networks has been suggested to be done so that from node u the next step is taken to neighboring node v that maximizes probability of direct link to target node t with formula $1 - (1 - p_v)^{\text{delta}_v}$ giving the probability that one of the delta_v friendships of v connect v to t (Simsek & Jensen 2005)</p>
<p>some estimates for modeling exploration in small-world networks (concerning random walks in one-hop replication networks that have a property that every node knows the identity or resources of its neighbors and thus can reply to queries on their behalf)</p>	<p>in a random walk in a small-world network the probability of revisiting a node increases as the number of hops increase and decreases when the average degree of network increases or the number of nodes in network increases (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 50000 nodes a random walk: when traversing 2000 hops managed to visit about 1600 nodes (about 3.2 percent) with average degree of 10, and about the same result was gained with average degree of 30 (Rodero-Merino et al. 2010); when traversing 10000 hops managed to visit about 7500 nodes (about 15 percent) with average degree of 10 and managed to visit about 8100 nodes (about 16 percent) with average degree of 30 (Rodero-Merino et al. 2010)</p> <p>coverage of a random walk in small-world network grows faster when the average degree of network is higher, an average search length grows linearly with the network size, and the bigger the average degree the shortest the searches are (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 100000 nodes a random walk traversing 2000 hops managed to cover about 3500 nodes (about 3.5 percent) of the network having an average degree of 10 and to cover about 67000 nodes (about 67 percent) of the network having an average degree of 30. (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 10000 nodes an average search length was about 950 hops when having an average degree of 10 and an average search length was about 200 hops when having an average degree of 30 (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 100000 nodes an average search length was about 9500 hops for average degree of 10 and an average search length was about 2000 hops for average degree of 30 (Rodero-Merino et al. 2010)</p>

Chapter 11. Adoption of knowledge based on Wikipedia linkage and spaced learning along language ability levels

We think that the proposed methods and experiments that we have introduced in Chapters 4–9 seemed to encourage for further research that extends to so many directions that our current research project cannot sufficiently cover them due to both time and space constraints. Chapters 1–3 introduced some background to motivate development of our proposed methods and then Chapters 4–9 described development of our proposed methods. After that in Chapter 10 we have tried to represent an overlook about principles that have been suggested in previous research to govern learning process as well as formation and exploration patterns of networks. Now after all those chapters we feel an emerging need to still carry out some experiments to estimate even at coarse level the range of needed knowledge structures and computational resources required to sufficiently represent essential knowledge management processes in educational purposes based on conceptual networks relying on the hyperlink network of the Wikipedia when dealing with any typical learning topic encountered by a learner during her cumulative adoption of knowledge from early years of childhood to full maturity of adulthood. In this chapter we now represent results that have been published in publications [P7] and [P8] and we hope that these remarks can enable to give a final overlook to our research done for this dissertation and especially how we consider that the most interesting features in our proposed methods described in publications [P1]–[P6] and findings achieved with them could be fruitfully synthesized cumulatively to serve as a pedagogical framework for computer-assisted education in real educational context.

11.1. Cumulative exploration in conceptual network relying on spaced learning

Motivated by previous research, in publication [P7] we propose a new educational framework based on method that adjusts sequential ordering and spaced repetition of conceptual structures to support adoption of new knowledge. We decided to develop a framework that adapts methodology introduced in publication [P6] although using now a bit different terminology (as will be explained a bit later in this Subchapter 11.1).

For each learning topic it is possible to define a *learning topic vocabulary*, a set of concepts covering its essential pedagogical knowledge in respect to learner's needs, that can be selected manually by learner or teacher, or be a high-frequency wordlist extracted for example from course book or lecture slideshow. To avoid semantic

challenges we currently accept only nouns to vocabulary. Learning takes place in series of sessions, for example one session per day or per week, each one focusing on learning a *session vocabulary* that is a subset of the learning topic vocabulary. A *pedagogic conceptual network* is generated by linking concepts of session vocabulary based on the shortest paths in hyperlink network connecting corresponding articles of English edition of Wikipedia encyclopedia (<http://en.wikipedia.org>). Each Wikipedia article represents a concept depicted by its title entry and all departing hyperlinks in this article define its relationships to other concepts. To find satisfactory definitions and redirects in cases of disambiguation and synonyms we used Wiktionary dictionary (<http://en.wiktionary.org>). A compact *relation statement*—containing main verb with some adjacent words—is extracted from sentence surrounding the departing hyperlink in article text to depict semantic relationship of linked concepts. In each learning session, learner cumulatively strengthens adoption of concepts belonging to pedagogic conceptual network as method shows step by step a sequence of chained relation statements based on routing generated to traverse conceptual linking of network. After reading currently shown relation statement, learner presses button “Next” to proceed to seeing following one.

Please note that now in publication [P7] we use “session vocabularies” and “learning topic vocabularies” that have similarity with “key vocabularies” introduced in publication [P6] and similarly now in publication [P7] we use “pedagogic conceptual networks” that have similarity with “learning concept networks” introduced in publication [P6]. However, there are essential differences that we explain in the following.

In publication [P6] key vocabularies are identified by selecting a set of concepts with the highest frequencies in a representative text sample and each learning concept network is built by connecting concepts of the key vocabulary based on the shortest hyperlink chains between corresponding Wikipedia articles (as explained in Subchapter 9.2). Thus all arriving and/or departing hyperlinks of concepts of key vocabularies cannot necessarily become well exploited since the approach of selecting the highest-ranking concepts from text samples can exclude certain concepts that have important position in connectivity of hyperlink network. In contrast, in publication [P7] irrespective of what concepts belong to session vocabulary or learning topic vocabulary all arriving and/or departing hyperlinks for their concepts can typically become well exploited since pedagogic conceptual networks are generated with an approach that gradually expands *coverage of concepts* that have important position in connectivity of hyperlink network. Thus while in publication [P6] the proposed model highlighted combined use of three complementing perspectives, now in publication [P7] an emphasis is given to *gradually expanding conceptual networks*.²²

²² Following additional notions can be also made about relatedness between “session vocabularies”, “learning topic vocabularies” and “key vocabularies” as well as between “pedagogic conceptual networks” and “learning concept networks”. While there are different key vocabularies for each of three complementing perspectives (learner’s knowledge, learning context and learning objective) as explained in publication [P6], now in publication [P7] session vocabulary and learning topic vocabulary typically refer to such vocabulary entity that covers at least partially each of these three key vocabularies and thus also their shared vocabularies, i.e. concepts that are shared by each pair of learning concept networks,

While traversing step by step each hyperlink in pedagogic conceptual network the learner becomes fruitfully exposed to associative mixture of old and new knowledge in a sequential process having tailored variation and repetition computed based on theory of *spaced learning*. We call this traversed route as a *learning path*. In the proposed framework our motivation to make the learner’s exploration in hyperlink network to be guided along principles of spaced learning originates from previous research that has shown benefits of spaced learning when compared to non-spaced learning, as already discussed in Subchapter 10.6. For example, a meta-analysis of 317 experiments (Cepeda et al. 2006) concluded that when compared to non-spaced learning, spaced learning of items consistently showed benefits regardless of retention interval, and learning benefits increased as time lags increased between learning presentations, and furthermore interstudy intervals producing maximal retention increased as retention interval increased. Principles of spaced learning has been motivated by findings in neurobiological activities ((Kandel 2001); (Fields 2005)) as explained in Subsection 10.6) and educational activities ((McKeown et al. 1985); (Hunt & Beglar 2005); (Karpicke & Roediger III 2007); (Cepeda et al. 2006); (Vlach & Sandhofer 2012)) as explained in Subsection 10.6), and computational methods to support learning have been proposed relying on spaced learning ((Wozniak & Gorzelanczyk 1994); (Pavlik & Anderson 2008)) as explained in Subsection 10.3 and Subsection 10.7).

Figure 11.1 (originally published as Figure 1 in publication [P7]) shows an excerpt of a learning path based on traversing concepts in a small pedagogic conceptual network going through a link chain Family->Child->Parent->Birth. Dotted arrows indicate possible traversal routes in network and solid arrows route that forms learning path this time. Concepts traversed recently and requiring spacing before being traversing again are in parenthesis. The learning path is shown to the learner as a sequence of following relation statements extracted from Wikipedia articles: “*Family* helps in socialization process of child”, “*Child* defines a relationship to parent or authority” and “*Mother* is a parent who performs the birth”.

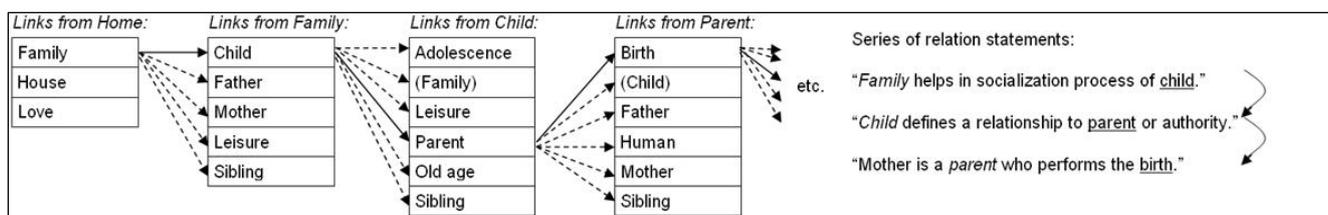


Figure 11.1 (originally published as Figure 1 in publication [P7]). An excerpt of a learning path and sequence of extracted relation statements shown to the learner.

called as learner–context vocabulary, context–objective vocabulary and learner–objective vocabulary (as explained in Subchapter 9.2). Similarly now pedagogic conceptual network typically refer to such conceptual network that covers at least partially each of three learning concept networks (corresponding to learner’s knowledge, learning context and learning objective) and thus also their shared segments belonging to a minimal collection of the shortest hyperlink chains that connect all concepts belonging to a pair of learning concept networks, called as learner–context routing, context–objective routing and learner–objective routing (as explained in Subchapter 9.2).

User interface of a prototype tool implementing the framework has three parts. One by one, *learning path illustration area* shows to learner the relation statement encountered next along learning path, supplied with static or animated visualization. *Concept map area* enables learner to draw concept maps during initialization and intermittent retention tasks. *Control panel* enables learner to adjust manually all parameters affecting learning session if needed. Learning session is constrained by parameters and values adjusted by learner's activity. Based on learner's needs and teacher's advice or earlier testing, learner manually sets parameters of current session: *session vocabulary size*, *degree of new content*, *session duration*, *learning speed*, *degree of required adoption*, *degree of exposure repetition*, *degree of retention repetition*, *interval of exposures* and *interval of retentions* (defined in Table 11.1 (originally published as Table 1 in publication [P7])).

Table 11.1 (originally published as Table 1 in publication [P7]). Parameters of the framework affecting the learning during learning session.

<i>Parameter</i>	<i>Definition</i>
Session vocabulary size	Amount of different concepts traversable in pedagogic conceptual network during learning session
Degree of new content	Percentage of previously unknown concepts in session vocabulary to be exposed to during learning session
Session duration	Available time for learning session
Learning speed	Aimed rate to traverse links (relation statements) per minute along learning path
Degree of forgetting	Probability that the meaning of an encountered concept is not remembered in a random next future encounter
Degree of required adoption	Minimum value of probability that meaning of an encountered concept is remembered in a random next future encounter and which is a probability value considered sufficient for a concept to be declared as learned well
Degree of exposure repetition	Minimum number of spaced exposures of a concept needed to learn it well
Degree of retention repetition	Minimum number of spaced retentions of a concept needed to learn it well
Interval of exposures	Minimum time between spaced exposures of a concept needed to learn it well
Interval of retentions	Minimum time between spaced retentions of a concept needed to learn it well

When starting new learning session the method first evaluates the learner's initial conceptualization level with following process. The method asks learner to indicate desired new learning topic by naming one or more familiar concepts about it which defines initial form of session vocabulary. These concepts are cross-linked based on the shortest hyperlink chains in Wikipedia to create initial form of the pedagogic conceptual network. Method now automatically extends initial form of pedagogic conceptual network to cover as many concepts as defined by parameter "session vocabulary size" by progressively uniformly linking new concepts to it according to how Wikipedia articles corresponding to current concepts have the nearest hyperlinked articles. These new concepts are also added to session vocabulary. Next, method generates a random excerpt of learning path containing 20 steps and shows its relation statements to learner in a sequence and then method asks learner to draw a concept map representing her best recall and understanding about concepts she just saw and how they were linked. Method

compares how much concepts and their links in concept map overlap with hyperlink structure of pedagogic conceptual network, and degree of matching between them defines parameter *degree of forgetting*, on scale 0.05–1.00 (overlap of 5–100 percent). Then method supplies each concept of pedagogic conceptual network with a value *measure of adoption* defined as $(1 - \text{degree of forgetting})$, estimating learner's probability to remember meaning of this concept in a random next future encounter.

Framework records evolution of learning path and learner can continue learning of previous session by loading from database learning paths and values achieved so far for each concept of learning topic vocabulary and pedagogic conceptual network. For each concept, framework keeps a record and updates five values. Besides “measure of adoption”, they include *measure of exposure repetitions* (number of spaced exposures of the concept so far), *measure of retention repetitions* (number of spaced retentions of the concept so far), *time between exposures* (average time between spaced exposures of the concept so far) and *time between retentions* (average time between spaced retentions of the concept so far). At each step of proceeding to next concept along learning path, all five values of that concept are updated. “Measure of adoption” is updated by formula based on cumulative multiplication of probabilities of forgetting:

$$\text{measure of adoption}_{n+1} = (1 - (1 - \text{measure of adoption}_n)(\text{degree of forgetting}))$$

When generating learning path, framework guides learner to traverse in pedagogic conceptual network at each step from current concept next to a concept having now the *lowest “measure of adoption”*, along the *shortest connecting hyperlink chain*. However, an additional restriction is that method aims to ensure fertile spacing between instances of traversing same concept again according to value “*interval of exposures*”. If several concepts share the lowest value, framework guides learner to traverse to that concept which is encountered first with *breadth-first search* starting from current concept. Learning path is generated at each step to proceed next only to concepts directly linked from previous concept. Due to naturally emerging clustering hierarchy of hyperlink network connecting session vocabulary, framework can somewhat prioritize such routes that give additional probability for traversing hubs in pedagogic conceptual network to reach distant concepts and links. Learner should traverse concepts with defined learning speed within 10 percent margin or framework recommends learner to adjust her speed. If session vocabulary contains more unknown concepts than value “degree of new content” allows, framework first generates such learning path that traverses only inside a subset of session vocabulary having number of unknown concepts low enough to qualify “degree of new content”. When unknown concepts of subset later gradually become learned due to spaced repetition, traversable vocabulary (subset) is cumulatively extended with additional unknown concepts.

We think that learning process can benefit if suitable amount of personal initiatives and spontaneous interactivity on lower level of granularity is offered to learner during exploration in hyperlink network even if on higher level of granularity the framework itself makes decisions about which exploration routes are made currently available to the student based on theory of *spaced learning*. Thus for example the learner can be

provided with a few alternative hyperlinks to proceed next and given an opportunity to actively select one of these according to his preference. Anyway we also think that to support adoption of concepts and also to cumulatively reinforce adoption of those concept that have not been yet fully adopted by student benefits from limiting the amount of available options during exploration thus contextually filtering out showing hyperlink alternatives leading to less relevant routes that might disturb concentration by excessive cognitive load.

Also it can be useful to let the student self intuitively and according to his own preference select routes to traverse as long as conditions based on spaced learning (that are automatically monitored on the background by the framework) become met and only after that gradually eliminate available hyperlinks shown to student and possibly indicating with a scale of color shades like traffic lights how much traversals remain currently still available for each hyperlink and how much the framework wants to promote proceeding each available hyperlink next. However it can be useful to show some alternative hyperlinks so that traversing them is not currently allowed (due to constraints based on spaced learning) but anyway the student has a possibility to see these alternatives to better adopt branching of exploration routes and how conceptual network enables diverse collection of parallel, crossing and overlapping routes and intermediate concept along paths when trying to find most optimal and descriptive routes connecting a pair of concepts.

With a spacing defined by parameter “interval of retentions”, method periodically interrupts proceeding along learning path with a *retention task* by asking learner to draw a concept map representing her best recall and understanding about concepts she just saw and how they were linked since the start of current learning session or since the latest retention task. Method compares how much concepts and their links in concept map overlap with hyperlink structure of pedagogic conceptual network, and degree of matching between them redefines “measure of adoption” for all concepts involved and also “degree of forgetting”. All concepts belonging to session vocabulary need to become traversed in pedagogic conceptual network along learning path so many times and with sufficient spacing that finally—due to repeated cumulative exposure and retention—for each concept value “measure of adoption” reaches “degree of required adoption”, “measure of exposure repetitions” reaches “degree of exposure repetition” and “measure of retention repetitions” reaches “degree of retention repetition”. Now each concept of session vocabulary has reached enough exposures and retention to be declared as learned well. Then—or if session has lasted longer than “session duration”—session ends and method reports “measures of adoption” for each concept of session vocabulary and supplementing statistic about evolution of learning path, like number of traversals per each hyperlink. These results are stored so that adoption of vocabulary can flexibly continue in future learning sessions.

Promisingly, learning paths suggested by framework seemed to match well learner’s needs when learning paths were generated by using such parameters that correspond to learning practices typical for successful spaced learning. In accordance with previous research, we suggested in publication [P7] based on our preliminary testing to use following approximate values for parameters.

“Session duration” of about 30 minutes and “session vocabulary size” of about 100 concepts may enable enough variation and spaced repetition (motivated by result that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes, and thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures (Fields 2005) and motivated by result that vocabulary of 100 concepts matches well with values of learning speed and degree of exposure and degree of retention that we define and explain just below since with learning speed of 10 traversed concepts per minute each of 100 concepts of session vocabulary becomes on average encountered 3 times in 30 minutes of session duration).

To avoid cognitive overload it seems promising to have about 5 percent as “degree of new content” and about 85 percent as the “degree of forgetting” (motivated by result that 95 percent coverage is sufficient for reasonable comprehension of text ((Nation & Waring 1997) referring to (Laufer 1989)) and motivated by result that chance of retaining meaning of a word is 5–20 percent (Hunt & Beglar 2005)). To maintain continuity of comprehension, “learning speed” could be about 10 traversed concepts per minute (motivated by result that for sufficient comprehension reading rate of at least about 200 words per minute (Anderson 1999) and average sentence length below 20 words (DuBay 2004) has been suggested thus resulting at least 10 sentences per minute corresponding to traversing a hyperlink with a relation statement).

For each concept at least value 3–5 is suggested as “degree of exposure repetition” and “degree of retention repetition”, and 10 minutes as “intervals of exposures” and “interval of retentions” to ensure it becomes learned (motivated by result that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes, and thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures (Fields 2005)). “Degree of required adoption” could be 95 percent so that with this probability the meaning of each concept is remembered in random next future encounter (motivated by result that 95 percent coverage is sufficient for reasonable comprehension of text ((Nation & Waring 1997) referring to (Laufer 1989))).

After publishing publication [P7] we have carried out an extended analysis discussed in Subchapter 10.1 and those supplementing later experiments seem to fruitfully verify findings of our earlier preliminary testing we just discussed here in Subchapter 11.1 including suggested approximate values for parameters of proposed framework. We think that features related to three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and features shown in Table 10.10, as discussed in Subchapter 10.1, can be considered to at least indirectly give strong experimental support to our suggestions here in Subchapter 11.1 that the student’s exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning.

In publication [P7] we propose that the student's exploration along learning path is supplied with a set of visualizations based on main verb identified in relation statements extracted from sentences surrounding hyperlinks in Wikipedia articles. In previous research it has been shown that kindergarten children can learn to use strategies based on semantic integration of meaningful sentences relying on pictographs and these strategies can be transferred to other similar tasks (Ryan et al. 1987). An early influential work was defining international picture language suggested for varied educational purposes based on agreed compact visualizations (Neurath 1936). Despite being popular, many proposed abstract visual symbolic languages can be challenging to intuitively understand especially in chained and agglomerated conceptual relationships, and critical empirical evaluation of their suggested benefit for comprehension has been largely missing (Lin & Biggs 2006). Watson and Moritz (Watson & Moritz 2001) proposed a developmental model with four response levels dealing with how students arrange pictures to represent data in a pictograph, how they are interpreted and used to make predictions. It has been shown that despite somewhat decreased use of pictographs in later school years they can be used to support diverse tasks for example in counting skills and appreciation of variation and uncertainty in prediction (Watson & Kelly 2003). Gordon proposed using interactive comics for collaborative learning by letting online discussion to be represented with learner-driven editing of contents of a four-frame comic strip (Gordon 2006). It is typical that even complex abstract visual notations convey meanings that have diverse references to specific languages and cultural contexts (Unger 2003).

In the framework of publication [P7] we suggest that while the learner proceeds the links in pedagogic conceptual network, each shown relation statement is supplied with a visualization to help conceptualization of the relationship between the pair of concepts of the current link. While traversing the learning path, at each step the learner is provided with a list of concepts linked to from the current concept and relation statements depicting these relationships, supplied with a visualization to help conceptualization of the relationship between the pair of concepts of each link. Figure 11.2a shows an example of this list when the current concept is Parent and the concepts linked to from current concept include Birth, Child, Human, Father, Mother and Sibling. When the learner, based on her needs and intuition, selects with mouse one of the linked concepts (shown in the column "Next concept"), her exploration proceeds one step further in the pedagogic conceptual network so that the selected concept becomes now current concept and the list becomes updated to represent which concepts are linked to from this new current concept.

Visualizations, shown at each step of proceeding links in pedagogic conceptual network, are collaboratively created and edited by community of learners in wiki style with an aim to gradually enhance illustrative effect of visualizations and at the same to enable collaboratively individual learners to increase their personal skills of creating works of illustrative visual art and adoption of evolving conventions of visualization. Each visualization can be done with any technique but is supposed to be in a form we call as *drawn sketch of illustrative visual art*, i.e. a drawing created quickly intuitively to represent the learner's, who is drawing, current personal conceptualization about

current relation statement in a form that is as compact, illustrative and universally understandable as possible. Visualizations for each relation statement should be collaboratively created and edited so that their compact yet illustrative nature becomes constantly enhanced and an ontology becomes cumulatively defined for network of visualizations about the learning topic and for the learner's personal conceptualization concerning it. Aim is that while exploring visualizations each student can learn about their traditional yet evolving conventions and on the other hand further contribute to defining at least partially shared language of visualization based on drawn sketches, thus closely resembling ideology of developing information graphics that visualize data innovatively.

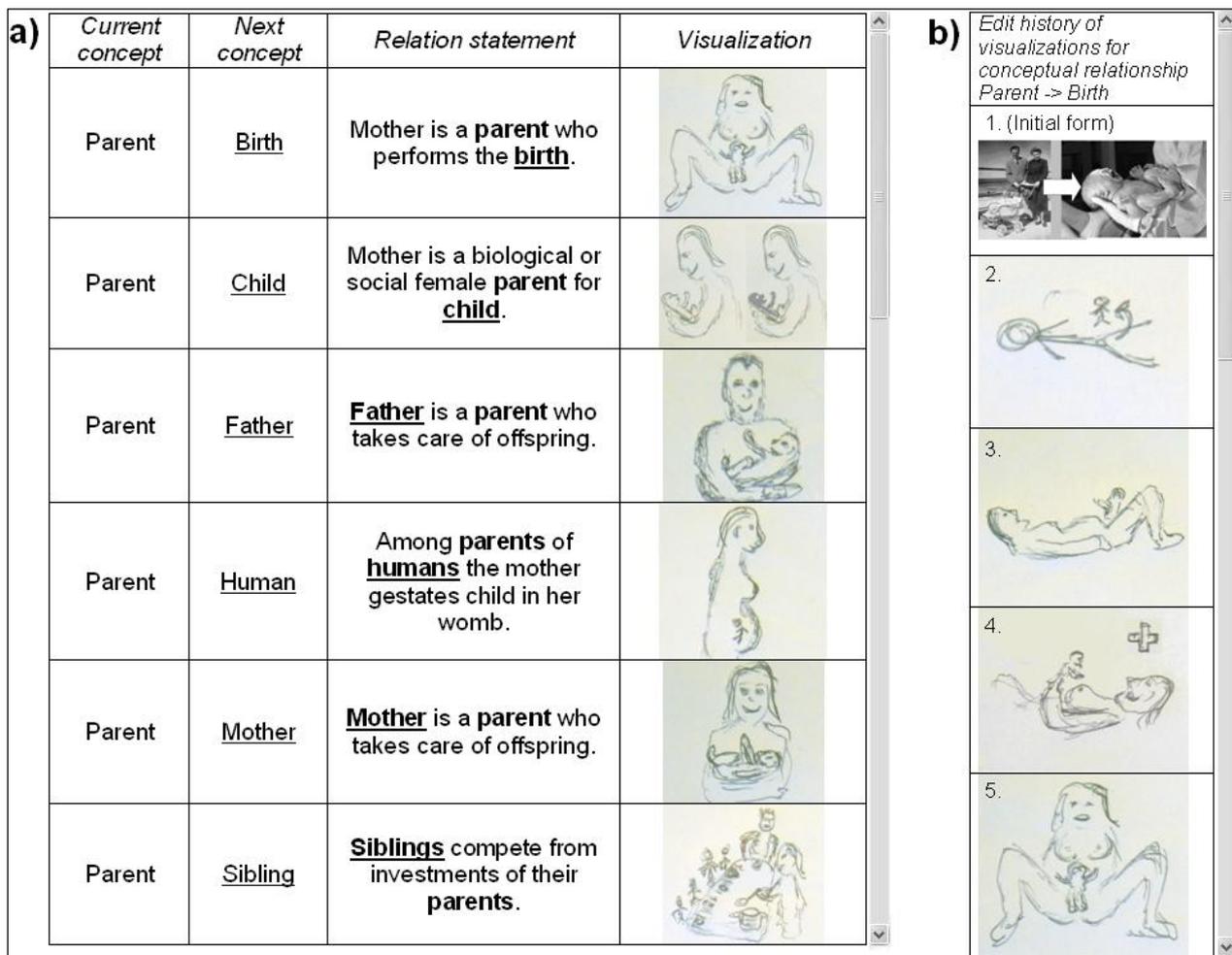


Figure 11.2. a) A list of concepts linked to from the current concept and relation statements depicting these relationships, each supplied with a visualization, that are shown to the learner while traversing step by step along the learning path. b) A view from edit history showing few consecutive temporal versions of visualizations created to illustrate conceptual relationship leading from Parent to Birth. (For the license of two photos, both stored at Wikimedia Commons, see http://commons.wikimedia.org/wiki/File:PikiWiki_Israel_4062_A_pair_of_immigrants_and_a_child.jpg and <http://commons.wikimedia.org/wiki/File:HumanNewborn.JPG>.)

By clicking with mouse at any visualization the learner gets full access to edit history of this visualization an enabling to create a new version of this visualization based on earlier versions and according to her own intuition. A full access to edit histories of all visualizations is provided with an educational aim that the modifications and

refinements to visualizations could be done so that a gradual cumulative development of visualization is achieved based on the earlier versions. In case of largely unsatisfied version there remains a direct access to revert to earlier versions of visualization. In Figure 11.2b is a view from edit history showing few consecutive temporal versions of visualizations created to illustrate conceptual relationship leading from Parent to Birth.

Each visualization consists of two *concept pictographs* representing concepts, extracted from the images of corresponding Wikipedia articles or queried from Wikipedia Commons open image database (<http://commons.wikimedia.org>), and a *transitional effect* (either static or dynamic) representing the relationship between concepts based on extracted relation statement. Static transitional effects consist of semitransparent still images placed over and between concept pictographs following visualization conventions of story-telling in comic strips and dynamic transitional effects consist of coordinating animation implementing movements and transformations of concept pictographs following visualization conventions of story-telling in cinema. A database of visualization conventions is collaboratively maintained for most frequently encountered key terms in relation statements and is queried to find most matching transition effect. To avoid semantic challenges transition effect is currently selected based on main verb identified in relation statement after it is supplied with part-of-speech tagging.

To aid development of effective visualizations the framework provides inspiration for further editing by creating an initial form of visualization which consists of two *concept pictographs* representing concepts of currently traversed relationship, extracted from the images of corresponding Wikipedia articles or queried from Wikimedia Commons open image database (<http://commons.wikimedia.org>), and a static *transitional effect* representing the relationship between concepts based on extracted relation statement. Static transitional effects consist of semitransparent still images placed over and between concept pictographs following evolving visualization conventions of story-telling in comic strips. A database for these visualization conventions is collaboratively maintained for the most frequently encountered key terms in relation statements and is queried to find most matching transition effect. To avoid semantic challenges transition effect is currently selected based on main verb identified in relation statement after it is supplied with part-of-speech tagging. In Figure 11.2b an initial form of visualization is generated by connecting a photo of parents (retrieved from Wikimedia Commons with query about Parent) and a photo of a newborn (extracted from Wikipedia article about Birth as of 1 November 2012) with an arrow indicating causality.

While the learner participates in collaborative editing of a visualization, reviews its edit history and explores the initially suggested visualizations consisting of concept pictographs and transitional effect she becomes involved in a diverse complementing processes of adoption of evolving conventions of visualization and skills of creating works of illustrative visual art. All activities of browsing in conceptual network and creating and editing visualizations are recorded to a log which offers a systematic way to track and analyze learning process thus helping educators and learners themselves in

management, modeling and coordination of conceptualization of new knowledge, enhancing personal creative skills and identifying specific areas needing support.

11.2. Cumulative exploration in conceptual network relying on growing vocabularies based on language ability levels

Motivated by previous research, in publication [P8] we propose a new educational framework based on guided exploration in small-world networks relying on hyperlink network of the Wikipedia online encyclopedia in which hyperlinks between articles define conceptual relationships. Educational material is presented to student with cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the distribution of enabled hyperlinks connecting concepts belonging to current vocabulary according to requirements of learning objective, learning context and learner's knowledge. Besides developing a computational method to manage educational material with conceptual networks and to explore the shortest paths between concepts of vocabulary (especially highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts), we have also experimentally estimated properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to six language ability levels.

Previous research has shown that *small-world networks* offer efficient compact link structures that seem to exist in many natural processes such as social networks (Uzzi et al. 2007). Using small-world networks can help to minimize paths required to form connectivity between nodes of the network and to maintain this property also when the network grows or experiences other modifications. Small-world topology has been identified structurally and functionally in human brain networks ((Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010)) and thus we think that representation of knowledge in form of small-world networks should be encouraged to support various knowledge management tasks and especially learning. Currently one of the biggest freely accessible knowledge resources is collaboratively built Wikipedia online encyclopedia and that has been shown to naturally represent properties of a small-world network (Ingawale et al. 2009).

Besides holding general small-world properties it has been identified furthermore that the Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)) and motivated by this we suggest that representation of knowledge for various purposes can benefit from having not only general small-world properties but furthermore having scale-free small-world properties. As already discussed in Subchapter 10.9, concerning network models Prettejohn et al. (Prettejohn et al. 2011) mention the model of Klemm and Eguílez (Klemm & Eguílez 2002) that offers both small-world and scale-free properties. Also as already discussed in Subchapter 10.9, Bullmore and Sporns (Bullmore & Sporns 2009) mention that some

studies with high spatial resolution have indicated that in organization of functional brain networks scale-free properties hold ((Eguíluz et al. 2005); (Van den Heuvel 2008)) and some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Motivated by previous research we propose in publication [P8] a new framework to support learning based on knowledge structures inspired by the hyperlink network of the Wikipedia and we supply this proposal with some promising experimental results relying on our empirical analysis of properties of conceptual networks that we have generated based on the Wikipedia.

We propose a method for *cumulative adoption of vocabulary* supported by representations of vocabulary in knowledge structures that are based on a small-world network (and possibly a scale-free version of small-world network being the most preferable). We think that due to properties of small-world network emerging inherently in various instances of nature ((Uzzi et al. 2007); (Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010); (Bullmore & Sporns 2009)), it is possible that learning of new knowledge can get useful support if new pieces of knowledge can be added to learner's previous knowledge entities in mind in a process that can be represented by *building a scale-free small-world network* and through its modification and exploration. We think that instead of just one small-world network there can be a great number of diverse parallel and partially overlapping and multidimensional small-world networks that can be used at the same time to represent knowledge both in educational material, such as texts, and in the learner's mind. We think that among students there are large individual differences in student's mental small-world networks representing his previous knowledge entity. Therefore to make new pieces of knowledge to become sufficiently fit into previous knowledge entity of student during learning process it is useful to offer personalized forms of representation of educational material.

Ellis (Ellis 2008) explains emergence of dynamic cycle of language use so that high-frequency of grammatical language elements can cause their erosion and homonymy thus affecting perception, learning and eventually language usage. Ferrer i Cancho and Solé (Ferrer i Cancho & Solé 2001) mention that sequential co-occurrences of words in sentences can be represented in network form that shows small-world properties enabling average number of steps needed to proceed along links from a word to any other word to be in range of 2–3 steps. Kinouchi et al. (Kinouchi et al. 2002) explain how a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step).

We think that our just discussed suggestion to support learning with knowledge structures having properties of small-world network (possibly preferably scale-free small-world network) can have some additional support from our previous analysis in Subchapter 10.1 concerning properties of three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and properties of exploration in hyperlink network discussed based on Table 10.10, and previous analysis

in Subchapter 11.1 about that the student's exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning.

An influential early work aiming to describe age-related development of a *learner's vocabulary* is a wordlist proposed by Dale and Chall (Dale & Chall 1948) defining 3000 words that were known by 80 percent of children attending school at grade 5. Based on British National Corpus XML edition ((Berglund 2007); (British National Corpus XML edition 2007)) containing tagging about contributing individuals of text and speech samples it has been possible to identify *variations of vocabularies* used by people of varying ages and to estimate how core vocabularies can form and evolve.

Hanhong and Fang (Hanhong & Fang 2011) identified that higher lexical coverage was gained when core vocabulary was selected based on word's dispersion index and distributed frequency in different age groups instead of raw frequency. Hanhong and Fang also found out that under 15-year-olds relied more on core vocabulary than older persons and along age increase core vocabulary of over 15-year-olds maintains a stable proportion of their vocabulary size. Furthermore Hanhong and Fang found out that each age group appears to acquire more core words relying on age-related frequency than raw frequency. Cromley (Cromley 2005) empirically analysed *reading comprehension* in respect to five contributing variables of vocabulary, background knowledge, interference, strategy and word reading suggesting based on path analysis that vocabulary and background knowledge which are two of the most distal variables give the biggest contribution to comprehension. Previous research has identified how the amount of daily vocalization evolves along age (Gilkerson & Richards 2009) and gender based differences of talking (Mehl et al. 2007) as well as time use for students along age covering for example school, additional studying, reading, being read to and for computer activities (Juster et al. 2004), as discussed in Subsection 10.7. Previous research has also identified annual amount of reading depending on student's reading test score (Anderson et al. 1988) and annual adoption of new concepts to student's vocabulary ((Nation & Waring 1997); ((Lehr et al. 2004) referring to ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)); ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990))), as discussed in Subsection 10.8 and Subsection 10.2.

Trying to keep our analysis transparent and comparable for other research in this field we carried out further experiments with such vocabularies that are based on generally accepted recommendations about measuring a person's evolving language ability along consecutive stages of learning and empirically identified representative conceptual distributions for each of these stages.

To address these aims, we considered that *Common European Framework of Reference for Languages* (CEFR) is useful since it offers guidelines about how to measure language ability with six progressive levels that have been supplied with illustrative descriptors created and scaled with Rasch modelling based on Swiss surveys in 1994–1995 covering 300 teachers and 2800 learners ((Council of Europe 2001); (North 1996/2000)). These six levels of language ability in increasing order of expertise have been labeled with names *A1 (Breakthrough)*, *A2 (Waystage)*, *B1 (Threshold)*, *B2 (Vantage)*, *C1 (Effective operational proficiency)* and *C2 (Mastery)*. First two levels

have been classified to represent abilities of a basic user, two next ones abilities of an independent user and two last ones abilities of a proficient user.

While establishing CEFRL has enabled efforts to define vocabularies needed for each language ability levels that can be compared between various European languages large incompatibilities have been identified concerning the size of sufficient vocabularies for each language ability level and some *vocabulary sizes* have been suggested in the following ranges: 400–3300 words for level A1, 800–4000 words for level B1, 1100–6800 words for level B2 and 3300–30000 words for level C2 (Kusseling & Decoo 2010). Since defining cut-off points between language ability levels is a subjective process it has been suggested that each level can be further divided hierarchically to sublevels with a branching approach that enables to address local needs while still maintain easy positioning in respect to commonly shared higher-level framework.

Level C2 (Mastery) has been defined so that it does not imply abilities of a native-speaker but instead such precision, appropriateness and ease with the language that typically belong to *highly successful learners*. Along formation of six levels of language ability of CEFRL some simple general task were identified in the Swiss surveys that were scaled below level A1 but can be defined as objectives for *beginners* of language learning, including making simple purchases, asking and telling time-related information, using basic greetings and expressions of politeness, filling easy forms with personal details and writing a simple postcard.

Working document of European Commission (European Commission 2012) mentions estimates made by non-profit assessment organisation Cambridge ESOL (meaning Cambridge English for Speakers of Other Languages) now known as *Cambridge English Language Assessment* (Cambridge English for Speakers of Other Languages / Cambridge English Language Assessment 2013) about how many *guided hours of learning* are required to reach the language ability levels A2-C2 of CEFRL including 180–200 hours for A2, 350–400 hours for B1, 500–600 hours for B2, 700–800 hours for C1 and 1000–1200 for C2.

Based on several hundred thousand examination scripts of *Cambridge Learner Corpus* and multi-billion word *Cambridge English Corpus* and sponsored by Council of Europe there has been an effort to define English vocabulary covering each of six language ability levels of CEFRL and this has been resulted in formation of *English Vocabulary Profile* that is a database aiming to represent all words and phrases learners know at each of six levels of CEFRL (Capel 2013). From online database of English Vocabulary Profile (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A) offered by Cambridge University Press we retrieved in June-July 2013 all words and phrases belonging to each of six language ability level ranging from A1 to C2. Thus we gained a series of *cumulative vocabularies* of six language ability levels of English Vocabulary Profile ranging from A1 to C2.

Since the six vocabularies gained from English Vocabulary Profile seemed to express such gradual evolution of a learner's vocabulary that are not clearly fixed to specific ages of the learner it seemed interesting to parallel English Vocabulary Profile to a resembling series of vocabularies that are fixed to specific age of the learner,

especially in years of childhood and early youth. In this respect we considered that a useful resource is *Oxford Wordlist* that defines high-frequency wordlists for five consecutive strongly age-related categories of learners. Oxford Wordlist has been created based on writing samples collected in Australian schools in 2007 from about 1000 students of *three first school levels* (labeled somewhat confusingly as “Preparatory” (1891 samples), “Year 1” (951 samples) and “Year 2” (934 samples)) gaining over 160000 words (Lo Bianco et al. 2008) and in 2009 from 896 students of *fourth and fifth levels of school* (labeled again somewhat confusingly as “Year 3” (1437 samples) and “Year 4” (1251 samples)) gaining over 315000 words (Bayetto 2010). According to our understanding, the last four of these five school levels correspond approximately to ages ranging from 6- or 7-year-olds to 9- or 10-year-olds and Preparatory level corresponds to a bit younger ages.

From online database of Oxford Wordlist (<http://www.oxfordwordlist.com/pages/search.asp>) we retrieved in June-July 2013 all words belonging to high-frequency lists of each of five school levels ranging from Preparatory level to Year 4 level, when performing downloading the only setting we varied was school year, thus keeping settings concerning gender, language, indigenoussness, school setting, location and text type always at option “any”. In further analysis we consider that the series of high-frequency word lists of five school levels of Oxford Wordlist can sufficiently well represent a series of *partially cumulative vocabularies* of these five school levels and thus we refer to each of these high-frequency word lists with term vocabulary. Even if this our decision is somewhat coarse we considered it still sufficiently useful to enable to get some preliminary results when generating cumulative conceptual networks.

It appeared to us that the series of vocabularies in English Vocabulary Profile can reflect vocabulary needs belonging to English-for-secondary language having varying ages that largely represent already maturity and culturally diverse global backgrounds whereas series of vocabularies of Oxford Wordlist can reflect vocabulary needs belonging to specific age categories of childhood and early youth having culturally somewhat shared localized national context (i.e. Australia).

Table 11.2 shows the *amounts of words* we retrieved from online databases of both English Vocabulary Profile and Oxford Wordlist. To keep our new experimental setup sufficiently simple and to maintain comparability with our earlier experiments we decided to limit our further analysis concerning words retrieved from Oxford Wordlist and English Vocabulary Profile only to common nouns. The words of English Vocabulary Profile are inherently labeled with part-of-speech tags thus helping to extract only nouns. Since we did not have access to any part-of-speech classification concerning Oxford Wordlist (i.e. in available listings of Oxford Wordlist words were not labeled with part-of-speech tags) in further analysis we decided to contrast each of five high-frequency wordlists of Oxford Wordlist with full list of nouns extracted from vocabulary of range of language ability levels A1-C2 of English Vocabulary Profile. Thus if a word belonging to a high-frequency wordlist of Oxford Wordlist was found to exist also in a full list of nouns extracted from vocabulary C2 of English Vocabulary Profile then this word was considered as a noun also in this high-frequency wordlist of

Oxford Wordlist. Even if this contrasting process possibly caused some concepts to be incorrectly accepted to be nouns in high-frequency wordlists of Oxford Wordlist we considered that this process was still sufficiently useful to enable to get some preliminary results. Please note that in following analysis the given exact values that we have computed based on vocabularies we retrieved from Oxford Wordlist and English Vocabulary Profile can contain unintentional small inaccuracies due to challenging computational process. Appendix AA shows all unique nouns we retrieved in June-July 2013 from cumulative vocabularies of English Vocabulary Profile for six language ability levels ranging from A1 to C2. Appendix AB shows all unique nouns in high-frequency lists we retrieved in June-July 2013 from Oxford Wordlist (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile) for five school levels ranging from Preparatory to Year 4.

Table 11.2. Properties of cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and six language ability levels of English Vocabulary Profile ranging from A1 to C2.

<i>Oxford Wordlist</i>			<i>English Vocabulary Profile</i>		
School level	Unique words in high-frequency list	Unique nouns in high-frequency list (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile)	Range of language ability levels reached so far	Unique language items (words or phrases)	Unique nouns
Preparatory	1923	685	A1	785	305
Year 1	2364	811	A1-A2	2382	880
Year 2	3041	1008	A1-B1	5327	1761
Year 3	4808	1412	A1-B2	9502	2707
Year 4	4949	1445	A1-C1	11908	3198
			A1-C2	15715	3710

From Table 11.2 it can be seen that when a learner reaches the range of language ability levels A1-C2 of English Vocabulary Profile she is expected to know 15715 *unique language items*. Among these 15715 language items we identified 5853 *unique words or groups of words* supplied with a part-of-speech tag signifying adjective, adverb, conjunction, determiner, exclamation, noun, preposition or pronoun (some words or groups of words were supplied with more than one parallel part-of-speech tags). With a closer examination, among these 15715 language items belonging to range of language ability levels A1-C2 we identified 3710 *unique nouns*.

We generated *conceptual networks* relying on the hyperlink network of *the Wikipedia* (as of in June-July 2013) connecting collections of nouns having gradually increasing sizes as indicated in Table 11.2 for both Oxford Wordlist and English Vocabulary Profile. Please note that in contrast with earlier analysis largely relying on Wikipedia hyperlink network dating from the beginning of March 2008 we used in this further analysis Wikipedia hyperlink network dating from late June and early July 2013.

Concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered *cumulative* so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous

ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only *partially cumulative* since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

However, it needs to be noted that, as show in Table 11.2, our analysis with collections of nouns having various sizes can be expected to represent indirectly *coverage of vocabulary* that is much larger than the number of nouns alone. Thus for example according to Oxford Wordlist a learner who has adopted already 1445 highest-ranking nouns of English (that can reflect vocabulary needs of school level “Year 4”) can be expected to have propably adopted at the same time already 4949 words alltogether (i.e. these 4949 words containing words from also other word classes than just nouns) and according to English Vocabulary Profile a learner who has reached range of language ability levels A1-C2 can be expected to manage 3710 nouns but at the same time probably already 15715 language items alltogether. We think that the range of vocabulary sizes we decided to use in our analysis can sufficiently well approximate vocabulary level processes of learning and knowledge management in human mind since our vocabulary sizes quite well approach and at least partially reach the range of vocabulary sizes suggested in previous research as suitable for reasonable human understanding.

With our method educational material is presented to student with cumulative conceptual networks based on hyperlink network of Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the *distribution of enabled hyperlinks* connecting concepts belonging to current vocabulary according to requirements of learning objective, learning context and learner’s knowledge. So far our method accepts only nouns to vocabularies since hyperlinks in the Wikipedia are typically defined to connect nouns but also other part-of-speech could be possibly exploited with a resembling approach.

Thus for *life-long learning* an ultimate aim can be to reach a maximal coverage of the conceptual small-world networks representing all human knowledge and besides that even some personal contribution could be done to supplement this heritage of human knowledge through own writings and other forms of conveying new knowledge to the community (and possibly a scale-free version of small-world network being the most preferable). On the other hand, we think that all knowledge entities can be seen to consist of a complex collection of interconnected, overlapping and nested small-world networks so that each separate new learning topic can be considered to be learned as an own specific small-world network that becomes gradually more and more connected also to other small-world network structures held already so far in the mind of student.

When creating a hyperlink network of vocabulary based on hyperlink network of the Wikipedia we suggest extracting a *relation statement* for each hyperlink of

Wikipedia from phrase surrounding hyperlink anchor of end concept in article text of start concept. For example for a hyperlink pointing from concept Music to concept Art one relation statement from article text of start concept Music is “Music is an art form whose medium is sound and silence.” (here hyperlink anchor underlined). We suggest that during exploration in hyperlink network of vocabulary when student traverses a hyperlink between concepts learning of this relationship is supported by showing to the student a relation statement corresponding to this hyperlink. Eventually a *learning session* consists of a chain of traversed hyperlinks and their relation statements that can be guided to proceed in a sequential process having tailored variation and repetition computed based on theory of spaced learning, as explained in our previous work in publication [P7] and discussed in Subchapter 11.1.

To enable implementing educational technology for practical educational activities for students we have carried out empirical experiments to try to identify some constraints of *conceptual scale-free small-world networks* and to better understand behavior of their properties. Thus besides developing a computational method for exploiting conceptual scale-free small-world networks to manage and explore educational material we now also report some preliminary findings of experiments about the properties of conceptual scale-free small-world networks that we have generated based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic.

Table 11.3 shows properties of *conceptual networks* that we have generated based on hyperlink network of the Wikipedia (as of June-July 2013) between concepts we retrieved from *English Vocabulary Profile* (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A) for cumulatively growing vocabularies corresponding to each of six language ability levels ranging from A1 to C2.

At the highest language ability level C2 we have the most extensive vocabulary that we call as vocabulary A1&A2&B1&B2&C1&C2 (i.e. including all six cumulative vocabularies of consecutive language ability levels A1, A2, B1, B2, C1 and C2 together) and we identified that it contains *15715 unique language items* (words or phrases) that include *3710 unique nouns*. Then we wanted to identify all possible hyperlinks that are connecting these 3710 unique nouns in hyperlink network of the Wikipedia and we found *25153 unique hyperlinks* so that they actually connected *2878 unique nouns* of these 3710 unique nouns. Appendix AC shows a full listing of all 25153 unique hyperlinks between 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns. Appendix AD shows for each vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each language ability level. For each observed vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from A1 to A1&A2&B1&B2&C1&C2.

Table 11.3. Properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2.

Vocabulary of language ability level reached so far (predicted* = only extrapolated estimates)	Unique language items (words or phrases) in vocabulary	Unique nouns in vocabulary	Unique Wikipedia hyperlinks connecting unique nouns in vocabulary	Unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary
A1	785	305	1007	248 (A1: 248)
A1&A2	2382	880	3868	706 (A1: 265; A2: 441)
A1&A2&B1	5327	1761	9566	1374 (A1: 273; A2: 465; B1: 636)
A1&A2&B1&B2	9502	2707	17448	2121 (A1: 280; A2: 473; B1: 682; B2: 686)
A1&A2&B1&B2&C1	11908	3198	21410	2470 (A1: 281; A2: 479; B1: 694; B2: 701; C1: 315)
A1&A2&B1&B2&C1&C2	15715	3710	25153	2878 (A1: 283; A2: 483; B1: 706; B2: 718; C1: 328; C2: 360)
3000–5000 unique nouns (reasonable 95 percent level comprehension), predicted*	12900–21500 *	3000–5000 *	20308–33846 *	2308–3846 *
8000–9000 unique nouns (non-native adult), predicted*	34400–38700 *	8000–9000 *	54154–60923 *	6154–6923 *
20000 unique nouns (native adult), predicted*	86000 *	20000 *	135385 *	15385 *
54000 unique nouns (general vocabulary), predicted*	232200 *	54000 *	365538 *	41538 *

Therefore it seems that at language ability level C2 the Wikipedia can offer interconnected linkage for about 77.6 percent (2878/3710) of nouns belonging to current noun vocabulary. Furthermore, among these 2878 unique nouns 2635 occur as start concept and 2310 occur as end concepts in connecting hyperlinks. According to our calculations each of these 2878 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 has an average value of 8.7 departing unique hyperlinks and a median value of 5 departing unique hyperlinks and an average value of 8.7 arriving unique hyperlinks and a median value of 5 arriving unique hyperlinks linking it to other

unique nouns belonging to same vocabulary A1&A2&B1&B2&C1&C2. In the entity of 25153 unique hyperlinks it appeared that for 4824 hyperlinks there was another hyperlink going also into opposite direction thus 2412 connections can be considered bidirectional.

Since applying the hyperlink network of the Wikipedia for educational activities relies on those nouns that actually happen to exist in hyperlinks, we wanted to estimate the *properties of the conceptual networks* we have generated in respect to size of *noun vocabulary* that is actually available for browsing in the Wikipedia along unique hyperlinks connecting unique nouns of vocabulary.

By comparing growth of values in columns of Table 11.3 along language ability levels ranging from A1 to C2 we approximated that the number of unique nouns in vocabulary is about *1.3 times* the number of unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary, and the number of unique language items (words or phrases) in vocabulary is about *4.3 times* the number of unique nouns in vocabulary, and the number of unique Wikipedia hyperlinks connecting unique nouns in vocabulary is about *8.8 times* the number of unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary. Based on these dependencies we extrapolated to Table 11.3 coarse predicted estimated values to represent four additional cases in which the number of unique nouns in vocabulary reaches such language ability levels that have been suggested in previous research to correspond to reasonable *95 percent level comprehension* (3000–5000 or just 2000–3000 word families ((Nation & Waring 1997); (Laufer 1989))), *a non-native adult* (8000–9000 word families (Nation 2006)), *native adult* (20000 word families (Nation & Waring 1997)) and *general vocabulary* (well over 54000 word families in English (Nation & Waring 1997)).

Naturally vocabulary sizes for different language ability levels can be represented with various *alternative motivations and estimates*. As discussed earlier, Nation and Waring (Nation & Waring 1997) concluded based on earlier research by Laufer (Laufer 1989) that about 95 percent coverage is sufficient for reasonable comprehension of text and can be reached especially in favourable tailored textual contexts with 3000–5000 word families or just 2000–3000 word families. As discussed earlier, however, Laufer and Ravenhorst-Kalakovski (Laufer & Ravenhorst-Kalakovski 2010) suggested that for independent reading comprehension second language learners should have a vocabulary of about 8000 words offering about 98 percent text coverage and for reading comprehension with some guidance and help they should have a vocabulary of about 4000–5000 words offering about 95 percent text coverage. In addition, it has been claimed that the vocabulary of a 5-year-old contains 4000–5000 word families for native English speakers (Nation & Waring 1997) and that 95-percent understanding of junior or senior high school English-for-second-language textbooks required about 3000–3200 highest-ranking lemmatized words of British National Corpus (Chujo 2004).

Brezina and Gablasova (Brezina & Gablasova 2013) estimated that about 46 percent of 3000 highest-ranking words of British National Corpus are nouns ($0.46 \approx 1/2.2$) which is a greater ratio than a ratio based on our just mentioned approximation that there are 23 percent ($0.23 \approx 1/4.3$) unique nouns in unique vocabulary items of a vocabulary. Anyway since Wikipedia hyperlinks connect now only nouns we

assume that a student's explorations among 2878 unique nouns in 25153 unique hyperlinks connecting unique nouns of vocabulary A1&A2&B1&B2&C1&C2 can at least indirectly offer a conceptual exposure and coverage of 2.2–4.3 times greater amount of unique language items (i.e. containing also other part-of-speech than just nouns) meaning coverage of 6261–12522 unique language items. A student can gain this additional exposure for example by reading supplementing words in relation statements extracted from phrases surrounding hyperlink anchor in article text of start concept.

Therefore we suggest that hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns with 25153 unique interconnecting hyperlinks can be considered to offer sufficient knowledge structure to represent relatively reliably *conceptualization of everyday human vocabulary* corresponding to reasonable 95 percent level comprehension (3000–5000 or just 2000–3000 word families ((Nation & Waring 1997); (Laufer 1989))) that is defined based on cumulative iterative collaborative building process of Wikipedia online encyclopedia.

It can be seen from Table 11.3 that when proceeding to a vocabulary that is one step bigger (for example from range of language ability levels A1-A2 to range of language ability levels A1-B1) the increasing Wikipedia linkage does not originate only from the latest difference in vocabulary levels (for example addition of level B1 concepts) but it can partly originate also from concepts that belong to much earlier vocabulary (for example level A1 concepts and level A2 concepts) that emerge to Wikipedia linkage with a delay along with the latest vocabulary level (for example along addition of level B1 concepts).

Table 11.4 shows properties of *conceptual networks* that we have generated based on hyperlink network of the Wikipedia (as of June-July 2013) between concepts retrieved from *Oxford Wordlist* (<http://www.oxfordwordlist.com/pages/search.asp>) for vocabularies of each of five school levels ranging from Preparatory level to Year 4 level (as mentioned already earlier, when performing downloading the only setting we varied was school year, thus keeping settings concerning gender, language, indigenouness, school setting, location and text type always at option “any”, and furthermore nouns were extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile).

From Table 11.4 it can be seen that in vocabulary at the highest school level Year 4 we identified 1445 unique nouns and when we wanted to identify all possible hyperlinks that are connecting these 1445 unique nouns in hyperlink network of the Wikipedia in June-July 2013 we found 6759 unique hyperlinks so that they actually connected 1072 unique nouns of these 1445 unique nouns. Furthermore, among these 1072 unique nouns 971 occur as start concept and 898 occur as end concept in connecting hyperlinks. Appendix AE shows for each vocabulary of school levels ranging from Preparatory to Year 4 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each school level (as mentioned earlier, nouns were extracted from Oxford Wordlist based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile). For each observed vocabulary ranging from Preparatory to Year 4 a full listing of unique Wikipedia

hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from Preparatory to Year 4.

Table 11.4. Properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts for cumulative vocabularies of five school levels of Oxford Wordlist ranging from Preparatory to Year 4.

Vocabulary of school level reached so far	Unique language items (words or phrases) in vocabulary	Unique nouns in vocabulary	Unique Wikipedia hyperlinks connecting unique nouns in vocabulary	Unique nouns in Wikipedia hyperlinks connecting unique nouns in vocabulary
Preparatory	1923	685	2511	505 (Preparatory: 505)
Year 1	2364	811	2946	592 (Preparatory: 370; Year1: 592)
Year 2	3041	1008	4203	749 (Preparatory: 415; Year1: 460; Year2: 749)
Year 3	4808	1412	6750	1051 (Preparatory: 459; Year1: 520; Year2: 642; Year3: 1051)
Year 4	4949	1445	6759	1072 (Preparatory: 459; Year1: 512; Year2: 612; Year3: 825; Year4: 1072)

Therefore it seems that at school level Year 4 the Wikipedia can offer interconnected linkage for about 74.3 percent (1073/1445) of nouns belonging to current noun vocabulary. According to our calculations each of these 1073 interconnected nouns at school level Year 4 has an average value of 7.0 departing hyperlinks and a median value of 5 departing hyperlinks and an average value of 7.5 arriving hyperlinks and a median value of 5 arriving hyperlinks linking it to other nouns belonging to same Year 4 noun vocabulary. In the entity of 6759 hyperlinks for 1416 hyperlinks there was another hyperlink going into opposite direction thus 708 connections can be considered bidirectional.

It can be seen from Table 11.4 that when proceeding to a vocabulary that is one step bigger (for example from school level Year 1 to school level Year 2) the increasing Wikipedia linkage does not originate only from the latest difference in vocabulary levels (for example addition of level Year 2 concepts) but it can partly originate also from concepts that belong to much earlier vocabulary (for example level Preparatory concepts and level Year 1 concepts) that emerge to Wikipedia linkage with a delay along with the latest vocabulary level (for example along addition of level Year 2 concepts). Please note also, as mentioned earlier, that concepts of Oxford Wordlist and

Wikipedia hyperlinks connecting unique nouns of Oxford Wordlist are only partially cumulative for consecutive language ability levels.

We carried out *random path explorations* in hyperlink network of 25153 unique hyperlinks connecting 2878 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 so that any hyperlink can be traversed in both actual linking direction and opposite direction and all explorations were started from concept Human (starting from concept Human was motivated by our earlier finding that among 69 shared concepts in hyperlink network of the Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5). We reported initial findings in publication [P8] but later experiments indicated that those results were biased and gave too low numbers of visited concepts. Thus we report now here corrected results. A random path of 1000 steps visited about 651 unique concepts (23 percent) of 2878 unique concepts and 50 percent of visits stayed among about 188 unique concepts. Similarly with a random path of 10000 steps about 2032 unique concepts (71 percent) of 2878 unique concepts became visited and 50 percent of visits stayed among about 398 unique concepts, and furthermore with a random path of 100000 steps about 2765 unique concepts (96 percent) of 2878 unique concepts became visited and 50 percent of visits stayed among about 450 unique concepts.

It thus appeared that random path explorations in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 have a tendency to visit more certain subsection of hyperlink network and with a closer inspection we identified that these more visited concepts seemed to have relatively high position in hierarchy of connectivity of concepts in hyperlink network. Five highest-ranking positions of the most visited concepts in random path of 1000 steps were Wood (8 visits), Culture (7 visits), Science (7 visits) and Earth/Hobby/Plastic/Shoe/Soft_drink (5 visits), in random path of 10000 steps were Human (59 visits), Water (47 visits), Mammal (34 visits), Bird (33 visits), and Culture (31 visits), and in random path of 100000 steps were Human (457 visits), Water (411 visits), Philosophy (297 visits), Food (286 visits), Mammal (282 visits). It was interesting to note that with sufficiently large number of steps in random path explorations concept Human gained highest number of visits and this seems to indicate that concept Human has a central role in defining conceptual connectivity of hyperlink network. When we generated additional random path explorations starting from also other concepts than just concept Human it turned out that concept Human still remained as one the most visited concepts.

Just discussed results seem to indicate that in hyperlink network of vocabulary exploration relying heavily on random choices of student without systematic guidance can lead to relatively limited pedagogic gain due to visiting only limited subsection of all unique concepts and their unique connecting hyperlinks. Thus we suggest that pedagogically rewarding exploration in hyperlink network of vocabulary should actively exploit traversing the *shortest paths* connecting pairs of unique concepts of vocabulary. We think that in adoption of new knowledge the learner benefits from an opportunity to see intuitively the shortest connectivity between pieces of knowledge thus helping contextually to filter out less relevant things that might disturb concentration by excessive cognitive load, and using the shortest paths enables also

highlighting clustering structure of conceptual relationships to the student and generating a systematic efficient process to traverse in hyperlink network of vocabulary with an extensive diverse coverage.

We suggest that to support adoption of vocabulary a student's guided exploration in hyperlink network of vocabulary could proceed pedagogically rewardingly if exploration of the shortest paths *gradually moves* to cover new concepts related to concepts that have been adopted already earlier. On coarser level of granularity this gradual moving can be implemented by moving from vocabulary A1 to A1&A2 and then from vocabulary A1&A2 to A1&A2&B1 and so on. On finer level of granularity the guided exploration should gradually introduce new concepts belonging to current vocabulary and its most related subset of concepts concerning current learning topic while still also helping to refresh previously adopted concepts, with sequential tailored variation and repetition computed based on theory of spaced learning as explained in publication [P7] and discussed in Subchapter 11.1.

We also suggest that these new concepts should particularly include highest-ranking concepts of the topics that are intended to be learned so that exploration in hyperlink network of vocabulary could be performed especially by traversing the *shortest paths between the highest-ranking concepts* of previously adopted concepts and highest-ranking concepts of new concepts. In addition we suggest that, when available, *parallel alternative shortest paths* should be traversed between pairs of concepts to learn better the diversity of conceptual relations. With these suggestions we expect to establish efficient connectivity covering old and new concepts relying on dominant concept clusters of hyperlink network shown to student and that could then be also easier to conceptualize by the student.

We suggest that according to the needs of the learner new cumulative sets of vocabularies along gradually increasing adoption of new knowledge can be gained by generating high-frequency word lists from suitable text samples concerning intended learning topic or for example retrieving a desired set of words from resources such as British National Corpus (Leech et al. 2001).

We analyzed a *sample of 102 Wikipedia articles* selected to match 102 highest-ranking terms in texts generated by students, here we used the set of 102 core concepts introduced in Subchapter 3.10 and listed in Table 3.4 with results shown in Appendix G. These 102 articles had together hyperlinks to 20512 end concepts of which 14907 were unique and an article had on average 201 (median value 152) departing hyperlinks (as of 3 March 2008). When analyzing all 422 unique hyperlinks existing between these 102 Wikipedia articles (as of 3 March 2008) we found out that each start concept of a hyperlink had on average 4.1 (median value 3.5) *different end concepts*. Furthermore among all hyperlinks between these 102 Wikipedia articles we identified that there were on average 1.5 (median value 1) *parallel hyperlinks* (i.e. a certain end concept having more than one hyperlink anchors in article text of start concept) from each start concept to its end concept. For example, an article having two departing unique hyperlinks will on average have one of these two unique hyperlinks duplicated ($1.5 \times 2 = 3$). In addition we identified that in all 422 unique hyperlinks existing between the set of 102 Wikipedia articles in the article text of start concept the end concept was mentioned on

average 7.4 (median value 3) *different times*. On the other hand we identified that in the article text of each 102 articles on average 21.3 (median 20) *different concepts* corresponding to other 101 article titles were mentioned (i.e. resembling end concept).

Thus based on this sample of 102 articles it seems that when considering a noun vocabulary interconnected by Wikipedia hyperlinks, on average Wikipedia article has 1.5 hyperlink anchors for each hyperlink and the end concept of each hyperlink occurs 7.4 times in article text of start concept. Furthermore while about 4 percent (4.1/101) of concepts belonging to vocabulary can be actually reached via hyperlink from Wikipedia article it appears that about 21 percent (21.3/101) of concepts belonging to vocabulary are anyway mentioned in article text of an average Wikipedia article, meaning that number of potential relationships becomes multiplied with about 5 (0.21/0.04).

These results suggest that besides actually existing unique hyperlinks between concepts of a vocabulary and possible exploitation of parallel hyperlinks there exists a passive potential to extend current linking by establishing *additional supportive cross-linking* between all occurrences of concepts of vocabulary in all Wikipedia article texts of concepts of vocabulary²³. These findings suggest concerning vocabulary A1&A2&B1&B2&C1&C2 that hyperlink network which we so far managed to get to contain 2878 unique nouns with 25153 unique interconnecting hyperlinks can be extended progressively to contain much more hyperlinks, and using *multiplication factors* (1.5; 7.4 and 5) motivated above leads to an estimated range of 37730–186132 *hyperlinks*. By generating these supplementing hyperlinks we expect to increase diversity of linkage thus offering extended variation in exposure and coverage of a student's exploration in hyperlink network to adopt conceptual relationships and knowledge in general.

Although these compared values represent different temporal versions of the Wikipedia (from beginning of March 2008 and from June-July 2013) this comparison seems to indicate that even a relatively small collection of 102 *Wikipedia articles* can offer with its hyperlinks (14907 hyperlinks unique to collection of 102 observed core concepts) so large coverage of different hyperlinked concepts that this coverage somewhat approaches such levels of vocabulary that can be considered to represent *knowledge of a well-educated human* (language ability level A1-C2 containing 3710 nouns, connected with 25153 Wikipedia hyperlinks containing 2878 unique nouns).

We carried out experiments to identify how the shortest paths in hyperlink network of vocabulary evolve when observed vocabulary is cumulatively expanded thus introducing new interconnecting hyperlinks and intermediary concepts that enable *emergence of gradually shorter paths* between pairs of concepts of vocabulary as well as increase in the number parallel alternative paths. We experimented with vocabularies ranging from vocabulary A1 with 1007 unique interconnecting hyperlinks to vocabulary A1&A2&B1&B2&C1&C2 with 25153 unique interconnecting hyperlinks and the

²³ Please note that establishing this additional supportive cross-linking actually relies on feature that we described in Publication [P3] and Subchapter 6.2 as "*repetition of hyperlink terms*" when we described five features for ranking hyperlinks based on article statistics, and repetition of hyperlink terms denotes showing hyperlinks in a descending order of significance based on how many times the word (or group of words) forming the title of hyperlink's target article is mentioned in the current article, anywhere in its full textual content.

results seemed to support suggested pedagogic gains of using the shortest paths to guide educational exploration for adoption of new knowledge. In our experiments to generate the shortest paths in hyperlink network showing them in decreasing order of length of the path and also showing all alternative parallel paths having equal length we used Yen's algorithm to compute top k shortest loopless paths with sufficiently high values of k (Yen 1971).

For example we analyzed how the *available shortest paths* evolve between start concept "question" and end concept "school" when expanding observed vocabulary cumulatively from A1 to A1&A2&B1&B2&C1&C2. With *vocabulary A1* the shortest paths require traversing eight consecutive hyperlinks and there is only one path of this length: question -> problem -> business -> restaurant -> food -> supermarket -> book -> homework -> school. With *vocabulary A1&A2* the length of the shortest path has decreased to three hyperlinks and again there is only one path of this length: question -> quiz -> game -> school. With vocabularies bigger than A1&A2 the length of the shortest path does not anymore decrease from three hyperlinks but new alternative parallel paths emerge thus introducing diversity to express the characteristics of relationship of concepts (please note that those shortest paths found with smaller vocabularies remain available also with bigger vocabularies). With *vocabulary A1&A2&B1* two new alternative parallel paths emerge including question -> grammar -> education -> school and question -> information -> education -> school, and with *vocabulary A1&A2&B1&B2* five new paths include question -> philosophy -> psychology -> school, question -> philosophy -> government -> school, question -> theory -> education -> school, question -> theory -> psychology -> school and question -> concept -> psychology -> school. With *vocabulary A1&A2&B1&B2&C1* one new alternative parallel path emerges including question -> proposition -> psychology -> school but *vocabulary A1&A2&B1&B2&C1&C2* does not introduce any more new paths (i.e. vocabulary A1&A2&B1&B2&C1&C2 offers nine parallel paths) which can possibly even indicate that already with this size of vocabulary some kind of saturation has been reached in formation of somewhat optimal connectivity between these two concepts of human knowledge in respect to shortness of paths and diversity of parallel paths.

11.3. Estimated properties of explorations based on cumulative vocabularies and conceptual networks

We have now explained our experiments creating estimates about the sizes of hyperlink networks that can match with language ability levels from A1 to C2 of English Vocabulary Profile, and also estimates about the sizes of hyperlink networks that can match with sizes of vocabularies covering language usage needs for reasonable 95 percent level comprehension, non-native adults, native adults and general vocabulary. We have also estimated how already hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns with 25153 unique interconnecting hyperlinks can be extended to offer much more hyperlinks based on

article texts defining unused potential relationships and possible exploitation of parallel hyperlinks. We have also experimentally identified very limited coverage gained with random paths in hyperlink network of vocabulary and thus we have suggested using the shortest paths to guide educational exploration for adoption of new knowledge, and with cumulatively growing vocabularies the length of shortest paths can usefully decrease and alternative parallel paths offering diversity can be gained. We do not know any previous research proposing same kind of approach and results that we have presented here and we hope that our suggestions can open promising new perspectives to learning. Based on our experiments and analysis in publication [P8] we next explain some further *suggestions for educational use* of hyperlink network of vocabulary and we hope these ideas can offer inspiration for future work in both on research agenda and in real-life application to support personalized learning.

It is pedagogically useful that when observing the shortest paths to two *opposite directions* between a pair of concepts there often emerges two *different routings* offering new perspectives. For example with vocabulary A1&A2&B1&B2&C1&C2 from concept “love” to concept “memory” the shortest paths have two hyperlinks and there is only one path of this length: love -> psychology -> memory, and from concept “memory” to concept “love” the shortest paths have three hyperlinks and there are three alternative parallel paths of this length including memory -> psychology -> emotion -> love, memory -> psychology -> motivation -> love and memory -> learning -> emotion -> love. Besides identifying the shortest paths in both directions between a pair of concept we suggest that additional pedagogic potential of diversity and possibly even shorter paths become available when identifying the shortest paths in hyperlink network of vocabulary also so that any hyperlink can be traversed in both actual linking direction and opposite direction. When enabling these *bidirectional hyperlink traversals* in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2, from concept “love” to concept “memory” the shortest paths have length of two hyperlinks and there are three alternative paths of this length: love -> psychology -> memory, love -> loneliness -> memory and love -> mind -> memory.

We think that pedagogically useful exploration in hyperlink network of vocabulary could benefit from exploring especially those shortest paths that exist between the *highest-ranking hyperlinked concepts* and *strongly rising hyperlinked concepts* of vocabulary. Therefore we have generated some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for cumulative vocabularies of both five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and six language ability levels of English Vocabulary Profile ranging from A1 to C2 as shown in Tables 11.5–11.9.

Table 11.5. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2. In this table occurrences as start concepts and end concepts are analyzed together in joint form (i.e. occurrences as start/end concept).

Oxford Wordlist: Preparatory, as start/end concept		Oxford Wordlist: Year 1, as start/end concept		Oxford Wordlist: Year 2, as start/end concept		Oxford Wordlist: Year 3, as start/end concept		Oxford Wordlist: Year 4, as start/end concept			
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising		
water (69)	N/A	water (71)	milk (30->7)	water (84)	light (25.5s->13.5s)	water (111)	fruit (15->7.5s)	water (113)	skin (44->29.5s)		
animal (57)	N/A	food (65)	red; tiger (21.5s->15.5s)	human (79)	wood (19.5s->13.5s)	human (104)	music (61.5s->25.5s)	human (111)	grass (51->33)		
food (55)	N/A	animal (61)	sheep (58->19.5s)	animal; food (73)	science (78->18.5s)	food (90)	road (72.5s->29.5s)	food (85)	house (55->37.5s)		
bird (45)	N/A	bird (51)	day (39.5s->19.5s)	insect (55)	bread (25.5s->18.5s)	animal (80)	mind (35.5s->29.5s)	animal (79)	life (92.5s->42)		
earth (40)	N/A	fish (47)	meal (25->22.5s)	earth (53)	bat (29->24.5s)	earth (77)	butter (53->36)	earth (78)	fear (83->47.5s)		
fish; sun (38)	N/A	earth (46)	family (66.5s->25.5s)	bird (52)	dog (25.5s->24.5s)	fruit; meat; oxygen; sun (62)	rain; sausage (43->36)	transport (63)	shoe (67.5s->47.5s)		
fruit (37)	N/A	milk (39)	bread (30->25.5s)	fish (50)	art (58->31)	fish (61)	skin (72.5s->44)	plant; sun (62)	bone (61->47.5s)		
wood (34)	N/A	time (37)	bat (39.5s->29)	meat (46)	paper (49->35.5s)	bird; plant (60)	seed (67->44)	energy (60)	door (113->54)		
time (33)	N/A	nature (36)	cheese; year (88.5s->34.5s)	plant (44)	ocean (42->35.5s)	transport (55)	sky; snow (61.5s->44)	bird (59)	death (83->54)		
light; meat; plant; wind (30)	N/A	meat; turkey (35)	soup (46.5s->34.5s)	time (43)	fire (78->43)	time (54)	kitchen (53->44)	entertainment; fruit; nature (58)	gas (132.5s->62)		
English Vocabulary Profile: A1, as start/end concept		English Vocabulary Profile: A1-A2, as start/end concept		English Vocabulary Profile: A1-B1, as start/end concept		English Vocabulary Profile: A1-B2, as start/end concept		English Vocabulary Profile: A1-C1, as start/end concept		English Vocabulary Profile: A1-C2, as start/end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (39)	N/A	water (81)	fruit (6.5s->3)	human (129)	science (38->6.5s)	human (188)	law (47.5s->26.5s)	human (209)	life (71.5s->51.5s)	human (227)	god (80->57)
water (34)	N/A	food (72)	animal (11->4)	water (122)	physics (20.5s->18.5s)	water (165)	business (47.5s->32.5s)	water (184)	emotion (86.5s->75.5s)	water (191)	emotion (75.5s->57)
month (33)	N/A	fruit (49)	time (13->5)	food (105)	art (31->21.5s)	food (133)	government (97.5s->41)	food (144)	death (96->85)	food (158)	death (85->61)
plant (26)	N/A	animal (43)	meat (14.5->7)	earth (78)	insect (20.5s->21.5s)	earth (113)	crime (146->44.5s)	mammal (129)	genetics (146->90)	mammal (137)	reality (100->75)
day; fruit; supermarket; year (25)	N/A	time (42)	sun (35.5s->9)	entertainment (74)	wind (25->31)	science (104)	chemistry (65.5s->44.5s)	earth (127)	health (122.5s->95)	earth; psychology (134)	reason (90->75)
bread; milk (24)	N/A	plant (41)	supermarket (6.5s->9)	science; time (73)	language (95->35.5s)	animal (101)	medicine (80->49)	science (118)	blood (103.5s->95)	philosophy (132)	politics (95->78.5s)
animal (23)	N/A	meat (40)	milk (9.5s->12)	transport (72)	film (51->35.5s)	philosophy (100)	history (47.5s->51.5s)	animal (117)	horse (109->100)	science (130)	horse (100->87.5s)
meal (22)	N/A	month; sun; supermarket (39)	bird (35.5s->15)	animal; fruit (71)	fish (31->35.5)	psychology (99)	knowledge (158->54)	philosophy (116)	trade (193.5s->105.5s)	animal (127)	war (165->93)
time (21)	N/A	milk; nature; toy (37)	music (28->15)	plant (69)	painting (42.5s->39)	culture (98)	money (97.5s->56.5s)	psychology (112)	bone (122.5s->116)	evolution (119)	civilization (122->99.5s)
meat; soup (19)	N/A	bird; bread; music (36)	bread (9.5s->15)	education (66)	temperature (42.5s->42)	carbon dioxide (97)	biology (72->56.5s)	evolution (109)	civilization; metal (133->122)	culture (118)	bone (116->99.5s)

Table 11.6. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 when considering for each language ability level only new concepts (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary). In this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately.

Oxford Wordlist: Preparatory, new	Oxford Wordlist: Year 1, new	Oxford Wordlist: Year 2, new	Oxford Wordlist: Year 3, new	Oxford Wordlist: Year 4, new
<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>
water (69)	nature (36)	human (79)	oxygen (62)	nature; entertainment (58)
animal (57)	turkey (35)	insect (55)	transport (55)	technology (49)
food (55)	butter (32)	plant (44)	iron; energy (53)	copper; cattle (45)
bird (45)	tool; goat (25)	wind (35)	species (48)	temperature; liquid (41)
earth (40)	god (24)	culture (32)	plastic; clothing (42)	steel (39)
fish; sun (38)	vegetable (23)	shoe (31)	supermarket; sunlight (40)	leaf (31)
fruit (37)	rainforest; painting; cooking (22)	mind (30)	soil (39)	goat (30)
wood (34)	money; life (21)	sausage; bone (29)	vegetable; muscle (38)	rainforest; pressure; coast (29)
time (33)	leaf; father (20)	kitchen (28)	weather; sugar (34)	society; gardening; fuel (25)
light; meat; plant; wind (30)	beef (19)	death (27)	television; taste; fear (32)	concrete (24)

Oxford Wordlist: Preparatory, new		Oxford Wordlist: Year 1, new		Oxford Wordlist: Year 2, new		Oxford Wordlist: Year 3, new		Oxford Wordlist: Year 4, new	
as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept
food (29)	animal (54)	nature (24)	turkey (33)	human (32)	human (47)	transport (39)	oxygen; iron (39)	entertainment (43)	copper (39)
water (27)	water (42)	painting; butter (16)	god (19)	shoe (27)	insect (33)	supermarket (27)	species (38)	nature (42)	temperature (34)
toy (25)	earth (33)	rainforest (15)	cooking; butter (16)	kitchen (23)	culture (24)	clothing (25)	plastic (34)	technology (30)	liquid (27)
shoe (22)	fish (32)	father (14)	wool; goat; baseball (15)	insect (22)	plant (23)	oxygen (23)	energy (31)	rainforest; cattle (21)	steel (26)
tiger; sky (20)	wood (30)	vegetable; tool (13)	money; life (14)	plant (21)	lead; heat (20)	energy (22)	soil (30)	gardening; coast (19)	cattle (24)
time; wind; red (19)	bird (29)	taste (12)	business (13)	wind; mind (20)	rice; bone (19)	title (21)	sugar (29)	emergency (17)	pressure (23)
meal; pet; game (18)	sun (27)	recycling; mask; lawn (11)	tool; nature; beef (12)	sausage (19)	radio (18)	vegetable; taste (20)	television (27)	goat (16)	society (20)
soup; party (17)	food (26)	leaf; goat; gift (10)	glass; crime; cotton (11)	skin; future; flight (17)	salt; disease; air (17)	scientist; reason; perfume; mixture; health; artist (19)	muscle (25)	parrot; leaf (15)	wool; technology (19)
bird; plant; blue; bread; bat; garden (16)	fruit (23)	skull; reason (9)	vegetable; season; potato; leaf; camel (10)	month; hobby (15)	history; fuel (16)	fear (18)	law (24)	scissors; liquid (14)	concrete (18)
meat; grass; sea; road; kitchen (15)	horse (22)	season; november; eye (8)	silver; fur; coffee (9)	force; cloud; banana (14)	wind; cancer (15)	sunlight; sense; mat (17)	sunlight (23)	steel; pear; glove (13)	nature; leaf; fuel; acid (16)

Table 11.7. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2 when considering for each language ability level only new concepts (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary). In this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately.

English Vocabulary Profile: A1, new	English Vocabulary Profile: A1-A2, new	English Vocabulary Profile: A1-B1, new	English Vocabulary Profile: A1-B2, new	English Vocabulary Profile: A1-C1, new	English Vocabulary Profile: A1-C2, new
as start/end concept	as start/end concept	as start/end concept	as start/end concept	as start/end concept	as start/end concept
food (39)	toy; nature (37)	human (129)	philosophy (100)	mammal (129)	dna (73)
water (34)	physics; light; insect (34)	earth (78)	psychology (99)	protein; bacteria (93)	sustainability (63)
month (33)	wood; leather (32)	entertainment (74)	carbon dioxide (97)	globalization (89)	conscience (62)
plant (26)	red; art (31)	transport (72)	oxygen; agriculture (92)	infrastructure (86)	virtue (61)
day; fruit; supermarket; year (25)	science; plastic (30)	education (66)	evolution (86)	nutrition (80)	immune system (59)
bread; milk (24)	temperature; salad; painting (29)	culture (63)	clothing (79)	extinction (62)	capitalism (57)
animal (23)	cooking (27)	technology (62)	carbon (75)	ecology (59)	perception (55)
meal (22)	sausage; chicken (26)	religion (58)	species (74)	archaeology (58)	astronomy (54)
time (21)	yellow; sound; health (24)	turkey; economics (54)	steel; copper (64)	density (56)	hierarchy (52)
meat; soup (19)	yogurt; ship; mail; blue (23)	mind; energy; cattle (52)	advertising (60)	perfection; gene (52)	famine (51)

English Vocabulary Profile: A1, new		English Vocabulary Profile: A1-A2, new		English Vocabulary Profile: A1-B1, new		English Vocabulary Profile: A1-B2, new		English Vocabulary Profile: A1-C1, new		English Vocabulary Profile: A1-C2, new	
as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept
food (22)	animal (21)	toy (30)	wood (32)	human (61)	human (68)	insurance; carbon (43)	carbon dioxide (70)	infrastructure (64)	mammal (91)	conscience (55)	dna (51)
month (19)	water (20)	nature (27)	leather (24)	entertainment (57)	earth (62)	clothing (41)	philosophy (69)	nutrition (63)	protein (81)	sustainability (47)	perception (37)
supermarket; party (18)	food (17)	red; painting (22)	temperature; plastic; light (23)	transport (50)	turkey (53)	reputation (38)	psychology (65)	globalization (58)	bacteria (65)	hierarchy; analogy (35)	astronomy (33)
plant; bread; meal (16)	fish; rice (16)	sky; salad (20)	insect (22)	technology; mind (35)	religion (42)	reality (36)	species; oxygen (60)	perfection (50)	gene (35)	famine; burial (34)	immune system (31)
soup (15)	day; year; milk (15)	hobby (18)	science; cooking (21)	scientist (29)	culture (41)	psychology (34)	agriculture (59)	mammal; loneliness (38)	reptile; density (34)	virtue (33)	artificial intelligence (30)
water; house (14)	month; fruit (14)	sausage; camping (17)	art (20)	education; cattle (26)	education (40)	theory; suffering; agriculture; abuse (33)	evolution (56)	ecology (32)	extinction; archaeology (33)	produce; immune system; capitalism (28)	capitalism (29)
lunch (12)	sugar; sun (13)	yellow; pink; physics; curry; blue; bat (16)	wool (19)	coast (25)	iron; economics (39)	oxygen; institution; economy (32)	copper (54)	evaluation (31)	logic (32)	narrative (25)	virtue (28)
fruit; time; garden; shoe (11)	meat (12)	ship; mail; health; artist; airport (15)	physics (18)	translation; tiger; future (24)	energy (35)	philosophy (31)	god (45)	innovation; extinction (29)	globalization (31)	propaganda (23)	crystal (24)
day; year; book; drink; november; game (10)	cheese; tea; sheep (11)	perfume; competition (14)	biology (17)	writer (23)	law (34)	evolution (30)	steel (42)	bacteria (28)	coal (29)	wilderness; drought; dna; ambiguity (22)	sin; narrative; infant (23)
milk; grass; tomato (9)	plant; time; bird; horse; television; computer (10)	sound; omelette; glove; cloud; chicken; bottle (13)	baseball (16)	title; taste; culture (22)	literature (32)	community; carbon dioxide; aluminium (27)	soil (39)	leadership; digestion; archaeology (25)	erosion (28)	intellectual; astronomy (21)	ritual; metaphor (22)

Table 11.8. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4. In this table occurrences as start concepts and end concepts are analyzed separately.

Oxford Wordlist: Preparatory				Oxford Wordlist: Year 1				Oxford Wordlist: Year 2			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (29)	N/A	animal (54)	N/A	food (34)	game (12.5s->6)	animal (58)	sheep (16.5s->12)	food (38)	meat (19.5s->6)	animal (68)	science (25.5->12)
water (27)	N/A	water (42)	N/A	water (30)	bat (19->9)	water (41)	meat (19->15.5s)	water; human (32)	sky (13->7)	water (52)	light (17->13.5s)
toy (25)	N/A	earth (33)	N/A	toy (25)	camping (30->14)	fish (40)	cheese (46.5s->19.5s)	toy (28)	chicken (42->31)	human (47)	art (42->24.5s)
shoe (22)	N/A	fish (32)	N/A	nature (24)	farm (58->19.5s)	earth (38)	time (24->19.5s)	shoe (27)	desert; house (34.5s->31s)	earth (42)	dog (34.5s->28)
tiger; sky (20)	N/A	wood (30)	N/A	tiger (23)	salad (39.5s->25.5s)	bird (35)	computer (58->22.5s)	meat; sky (25)	gardening; white (49->35.5s)	fish (40)	fat (58->31)
time; wind; red (19)	N/A	bird (29)	N/A	game (22)	milk (122->29)	turkey (33)	day (39.5s->25.5s)	bat (24)	bed (34.5->35.5)	wood (38)	life (34.5s->31)
meal; pet; game (18)	N/A	sun (27)	N/A	red (21)	day (39.5->29)	food (31)	grass (30->25.5s)	tiger; kitchen (23)	light (97->43)	turkey (37)	fire (49->35.5s)
soup; party (17)	N/A	food (26)	N/A	time; bat (20)	ship (30->29)	wood (27)	gold (75.5s->29)	insect; time; soup (22)	door; ocean; shark (58->43)	food (35)	metal (179->43)
bird; plant; blue; bread; bat; garden (16)	N/A	fruit (23)	N/A	meal; soup (19)	yellow (46.5s->34.5s)	milk; sun (25)	family (58->34.5)	plant; red; pet; game (21)	blue (49->43)	insect; bird (33)	lake (68->43)
meat; grass; sea; road; kitchen (15)	N/A	horse (22)	N/A	pet; sky; camping (18)	desert (39.5s->34.5s)	fruit; sheep; horse (21)	sport (51->34.5s)	bread; wind; mind; painting; party (20)	drink (97->53)	sun (31)	war (42->43)
Oxford Wordlist: Year 3				Oxford Wordlist: Year 4							
As start concept		As end concept		As start concept		As end concept					
High	Rising	High	Rising	High	Rising	High	Rising				
food (52)	red (15->7.5s)	animal (73)	fat (31->21)	human (53)	door (36->22.5s)	animal (73)	war (44->22.5s)				
water; human (48)	plant (13.5s->7.5s)	water (63)	music (43->29.5s)	food (48)	fear (73.5s->31)	water (67)	life (61->37.5s)				
transport (39)	sausage (24.5s->13)	earth (61)	wind (53->36)	water (46)	sound; garden (61->33)	earth (62)	clothing (73.5s->42)				
meat (35)	sea (24.5s->17.5s)	human (56)	snow (61.5s->44)	transport (45)	competition (67.5s->37.5s)	human (58)	gas (122.5s->47.5s)				
toy (34)	fruit (72.5s->20)	fish (46)	computer; disease; plantet; salt; war (43->44)	entertainm ent (43)	machine (61->37.5s)	sun; fish (44)	governmen t; heart (61->47.5s)				
sky (33)	road (43->25.5s)	wood (44)	cancer; rain (53->51)	nature (42)	perfume (67.5s->42)	bird (43)	pain (132.5s->54)				
plant; red (31)	skin (31->25.5s)	sun (43)	tree (53->55)	shoe (34)	cloud (55->42)	wood (41)	brain; medicine; river (83->62)				
shoe (30)	house (31->29.5s)	bird (42)	heart (72.5s->61)	toy (33)	blue (61->47.5)	copper (39)	blood; flower (73.5s->62)				
kitchen (29)	pizza (43->31.5s)	oxygen; iron (39)	butter (61.5s->61)	red (32)	death; hunting (83->54)	species (38)	baseball; grass; transport (92.5s->71.5s)				
time; sausage; soup (28)	ship (31->31.5s)	food; species (38)	glass; bread (53->61)	technolog y; sky (30)	day (73.5->54)	food (37)	ocean (92.5s->76.5s)				

Table 11.9. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2. In this table occurrences as start concepts and end concepts are analyzed separately.

English Vocabulary Profile: A1				English Vocabulary Profile: A1-A2				English Vocabulary Profile: A1-B1			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (22)	N/A	animal (21)	N/A	food (38)	water (9.5s ->2)	water (48)	sun (11.5s ->5.5s)	human (61)	time (12 ->7)	human (68)	science (20->6)
month (19)	N/A	water (20)	N/A	water (33)	shoe (13.5s ->5)	animal (41)	fruit (9.5s ->5.5s)	food (60)	book (15.5s- >14)	animal (67)	music (32 ->18.5s)
supermarket; party (18)	N/A	food (17)	N/A	toy (30)	game (18.5s ->7.5s)	food (34)	television (19.5s ->7.5s)	entertainment (57)	painting; kitchen (15.5s ->15.5s)	water (66)	plant (32 ->22.5s)
plant; bread; meal (16)	N/A	fish; rice (16)	N/A	supermarket; nature; shoe (27)	soup (8 ->7.5s)	wood (32)	sugar (11.5s ->7.5s)	water (56)	fruit (20.5s ->17.5s)	earth (62)	art (22 ->22.5s)
soup (15)	N/A	day; year; milk (15)	N/A	soup; game (25)	bread (6 ->9.5s)	fruit; sun (29)	bird (19.5s ->9)	transport (50)	artist (46.5s ->21.5s)	turkey (53)	business (36.5s ->28.5s)
water; house (14)	N/A	month; fruit (14)	N/A	month; bread (24)	time (13.5s ->12)	sugar; television (26)	meat (13 ->11.5s)	nature (46)	sausage (30- >21.5s)	science (49)	computer (41 ->31.5s)
lunch (12)	N/A	sugar; sun (13)	N/A	time; plant; party (23)	kitchen (40 ->15.5s)	bird (25)	milk (7 ->11.5s)	time (41)	sky; wind (20.5s ->21.5s)	food (45)	time (26 ->31.5s)
fruit; time; garden; shoe (11)	N/A	meat (12)	N/A	book; red; kitchen; painting (22)	book (18.5s ->15.5s)	meat; milk; leather; fish (24)	paper (31 ->20)	shoe (40)	pizza (26 ->26.5s)	wood (44)	history (78.5s ->34.5s)
day; year; book; drink; november; game (10)	N/A	cheese; tea; sheep (11)	N/A	meal (21)	wind (54.5s ->20.5s)	light; plastic; temperature; rice (23)	radio (49.5s ->26)	soup; toy (37)	sea (63.5s ->30)	sun (43)	physics (32 ->34.5s)
milk; grass; tomato (9)	N/A	plant; time; bird; horse; television; computer (10)	N/A	fruit; wind; salad; sky (20)	fruit (13.5 ->20.5s)	insect (22)	wine (31 ->26)	technology; mind (35)	meat (36.5s- >30)	religion (42)	language (66 ->40)
English Vocabulary Profile: A1-B2				English Vocabulary Profile: A1-C1				English Vocabulary Profile: A1-C2			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
human (98)	competition; science (48.5s ->18.5s)	water (93)	law (26.5s ->10.5s)	human (112)	abuse (50 ->21)	water (102)	genetics (65 ->50)	human (121)	philosophy (74- >44)	animal (108)	war (65.5s ->41)
food (78)	meat (30 ->18.5s)	animal (91)	government (50.5s ->25.5s)	food (86)	evolution (69->38)	animal (100)	medicine (70.5s- >53)	food (93)	cancer (80 ->58)	human; water (106)	logic (116 ->82.5s)
water (72)	reason (56.5s ->24)	human (90)	language (40 ->34.5s)	water (82)	oxygen (56 ->39)	human (97)	crime (84 ->59.5s)	water (85)	ship (94 ->70)	earth (101)	death (127 ->88)
entertainment (68)	crime (93 ->30.5s)	earth (84)	biology (44.5s ->40)	nature (75)	life (124 ->43)	earth (94)	statistics (90 ->65.5s)	nature (79)	death (92 ->74)	mammal (98)	police (127 ->95)
transport (66)	future (48.5s ->30.5s)	carbon dioxide (70)	chemistry (50.5s ->47)	entertainment (71)	title (77.5 ->64)	mammal (91)	aluminium (95.5s- >84)	entertainment (74)	evaluation (100- >81)	psychology (92)	profession (108 ->95)
nature (65)	music (37.5s ->34)	philosophy; turkey (69)	disease (65.5s ->51.5s)	transport (70)	rainforest (91.5s- ->67)	philosophy (83)	experiment (117- ->93.5s)	transport (72)	invasion (117- ->82)	philosophy (90)	contract (168 ->112)
mind (52)	culture (65- >44)	religion (68)	technology (50.5s ->51.5s)	infrastructure (64)	bird (124 ->79)	protein (81)	blood (108 ->93.5s)	nutrition (68)	creativity (109- ->87)	law (86)	climate change (148 ->112)
technology (48)	skin (80 ->50)	psychology (65)	society (56 ->55.5s)	nutrition (63)	cancer (143.5s ->80)	religion (78)	child; heart (108- ->101)	mind (66)	civilization (155- ->100)	protein; religion (85)	system (138 ->112)
time; shoe (47)	insect (65- ->50)	culture; law (64)	knowledge; war (109.5s ->59.5s)	globalization; mind (58)	milk (91.5s ->81)	psychology; carbon dioxide (76)	trade (158 ->108)	infrastructure (65)	mask (133 ->112)	science; carbon dioxide (80)	fear (168-> 121.5s)
plant (45)	garden; writer (56.5s ->61.5s)	science (63)	money (99.5s ->65)	shoe (54)	death (143.5s ->92)	turkey (75)	risk; tool (139.5s- ->116)	globalization (63)	cloud (127 ->119)	turkey (79)	mind (157.5s ->121.5s)

Table 11.5 offers an overview showing some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* and six cumulative vocabularies of *English Vocabulary Profile* so that in this table occurrences as start concepts and end concepts are analyzed together in *joint form* (i.e. occurrences as start/end concept). Table 11.6 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* when considering for each school level *only new concepts* (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary), and in this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately. Table 11.7 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for six cumulative vocabularies of *English Vocabulary Profile* when considering for each language ability level *only new concepts* (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary), and in this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately. Table 11.8 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* so that in this table occurrences as start concepts and end concepts are analyzed separately. Table 11.9 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for six cumulative vocabularies of *English Vocabulary Profile* so that in this table occurrences as start concepts and end concepts are analyzed separately.

Column “High” in Tables 11.5–11.9 lists some of the *highest-ranking hyperlinked concepts* (occurrences indicated in parenthesis), i.e. those concepts that have the highest number of unique departing hyperlinks (in case of highest-ranking as being a start concept) or the highest number of unique arriving hyperlinks (in case of highest-ranking as being end concept). Please note that while observing either only departing hyperlinks or only arriving hyperlinks we express number of only unique hyperlinks (either departing hyperlinks or arriving hyperlinks), then when observing number of departing/arriving hyperlinks we express number of hyperlinks that is just a sum of unique departing and unique arriving hyperlinks and therefore can contain overlap and thus in many cases is not number of only unique departing/arriving hyperlinks. This means in Tables 11.5–11.7 that the number of occurrences as start/end concept can contain at most two references to same hyperlinked concept, once as start concept of arriving hyperlink and once as end concept of departing hyperlink.

Column “Rising” in Tables 11.5–11.9 lists some of *strongly rising hyperlinked concepts*, i.e. concepts that seem to strongly rise in ranking position from previous smaller vocabulary to current bigger vocabulary in respect to number of departing or arriving hyperlinks (for example which of the concepts belonging to vocabulary A1 seem to get among the biggest increase in ranking position when observing these same concepts again in vocabulary A1&A2). We created shown list of rising concepts (change in ranking position indicated in parenthesis, suffix -s indicating shared ranking position) by browsing highest-ranking concepts in decreasing order and selected such

concepts which increased their ranking position by at least value 0.01 when for all vocabularies the ranges of ranking values had been first transformed to equal range of closed interval [0,1].²⁴

We think that a person's ability to adopt new knowledge based on the shortest paths between concepts is affected for example by the *length of the shortest paths*, the number of *alternative parallel shortest paths* and the number of different concepts belonging to *intermediary concepts* along paths. We think that among parallel paths those shortest paths that have highest number of shared intermediary concepts and especially such intermediary concepts that occur most often among paths are important paths to define meaning of relationship between a pair of concepts. On the other hand to express diversity of meanings those shortest paths are important which have *most distinctive routing* among parallel paths (i.e. minimizing sharing of concepts). Also longer paths than the shortest paths can complement meanings of conceptual relationships. We think that to adopt new knowledge a successful pedagogical exploration in hyperlink network of vocabulary could possibly benefit from such mental processes of student that have resemblance to traversing *average search paths* in network. Thus we suggest that conceptualization in the student's mind could benefit from having such guided exploration in conceptual networks that enables many explorations that do not explore directly only the shortest paths between concepts but instead extend to cover also some *sidetracks* and even *dead-ends*.

Motivated by previous research showing that in a small-world network of 10000 nodes has an average search path of 950 steps for average degree of 10 and average search path of 200 steps for average degree of 30 (Rodero-Merino et al. 2010) and that Wikipedia has mean out-degree 20.63 (median value 12) (Kamps & Koolen 2009), we thus coarsely estimate that *in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2* having average out-degree 8.7 (median value 5) and containing 2878 unique nouns to enable the student to at least weakly *conceptualize a single relationship* between a pair of concepts could possibly require exploring about *300 steps* in the hyperlink network of vocabulary. Since previous research showed that in the Wikipedia on average 4.573 hyperlink steps are between a pair of concepts (Dolan 2011), and similarly in Facebook social network the average number of relationship steps between two users is 4.74 (Backstrom et al. 2011), our coarse estimate of exploring 300 steps is about *66 times the average length of the shortest path* between a pair of concepts in hyperlink network of vocabulary.

It thus seems that the student's conceptualization of conceptual relationships can require many times more exploration steps in the hyperlink network than belong to exploring just the shortest paths. On the other hand, it is possible that when traversing one exploration path several concepts that become encountered along the path can be

²⁴ It should be noted that when observing vocabularies consecutively going from smaller vocabulary to bigger vocabulary there emerges a greater range of ranking values also when transformed to equal range of closed interval [0,1] and ranking values are not directly comparable per se (thus even if a concept gets a ranking value that is greater number seeming to indicate being now lower in ranking position it is possible that relatively the ranking position has in fact become higher). Anyway we have aimed to take into account relative rankings so that when comparing ranking positions and their change between various ranking value ranges distortion should be minimized in this analysis.

cumulatively conceptualized in parallel, and it is also possible that the number of steps needed in later explorations can decrease as some kind of memories about previous explorations help to guide later explorations.

Since earlier research estimates that children are daily exposed to hear about 12815 words (Gilkerson & Richards 2009) and produce 1000–2700 vocalizations (Gilkerson & Richards 2009), and adults speak daily about 15669–16215 words (Mehl et al. 2007), it seems to us that human learning ability apparently can easily manage knowledge adoption at least through listening at a daily rate of about 12815–16215 words. Based on earlier research it seems that *knowledge adoption through reading* can have somewhat lower levels than listening but still managing daily rate of about 1647–12967 words (Anderson et al. 1988) corresponding with an average length of 20 words in sentence (DuBay 2004) to reading 80–648 sentences which can take with a suggested reading speed 200 words per minute (Lewandowski et al. 2003) about 8–65 minutes. Motivated by these estimates we concluded based on earlier research, we suggest that adoption of vocabulary by *exploration in hyperlink network* of vocabulary can be usefully carried out in a daily process that resembles reading 80–648 sentences.

Since each hyperlink in the Wikipedia typically has its own phrase (in article text surrounding hyperlink anchor) defining the relationship between start concept and end concept, and since the shortest path between a pair of concepts has on average 4.573 hyperlink steps in the Wikipedia (Dolan 2011), knowledge adoption of 80–648 sentences per day can be considered to correspond to traversing shortest paths of about 17–142 average pairs of concepts in hyperlink network of vocabulary. Based on previous recommendations of about 3–4 spaced exposures to enable fertile learning ((Thalheimer 2006); (Fields 2005); (Kandel 2001)), it seems that traversing 17–142 shortest paths can be considered to correspond (i.e. when dividing the number of shortest paths by 3 or 4 to enable 3–4 repetitions) an aim to learn connectivity relying on the shortest paths for about 4–47 pairs of concepts with every daily session of exploring hyperlink network of vocabulary. This result can be contrasted with and seems to resemble earlier estimates that a student can adopt daily about 4–9 new words ((Lehr et al. 2004); (Kuhn & Stahl 1998); (Nation & Waring 1997)).

Instead of considering shortest paths of varying length we can make a simplifying assumption that language learning can be represented as a process of adoption of *direct relationships between nouns* belonging to a vocabulary and based on Table 11.3 for vocabulary A1&A2&B1&B2&C1&C2 this corresponds to adoption of 25153 unique Wikipedia hyperlinks connecting 2878 unique nouns in vocabulary. If we assume based on previously mentioned results ((European Commission 2012); (Cambridge English for Speakers of Other Languages / Cambridge English Language Assessment 2013)), that to reach the range of language ability levels A1-C2 requires about 1000–1200 guided hours of learning, then for learning each of 25153 direct relationships between 2878 concepts there is on average 143–172 seconds to be used. If we assume based on previously mentioned results a reading speed of about 200 words per minute ((Lewandowski et al. 2003); (Anderson 1999)) and a sentence length of about 10 words (DuBay 2004), during this given time range of 143–172 seconds it is possible to read about 477–572 words corresponding to 48–57 sentences. If this given time range is

divided to for example *six spaced learning sessions* including three exposure sessions and three retention sessions then each of these six sessions has about 24–29 seconds corresponding to about 8.0–9.5 sentences devoted to learn one of 25153 relationships between 2878 concepts. Of course this kind of modelling about learning process is only a coarse simplification but we think that it can be useful to analyze learning also with this kind of simplifications to develop new methods to support learning.

To evaluate educational gains of exploration in hyperlink network of vocabulary we carried out an experiment to find out what kind of exploration paths emerge if we create a set of conceptual networks by identifying *the shortest paths* between *the highest-ranking start concepts* and *the highest-ranking end concepts* in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9. Thus we identified the shortest paths leading from 10 highest-ranking start concepts (including (occurrences in parenthesis): human (121), food (93), water (85), nature (79), entertainment (74), transport (72), nutrition (68), mind (66), infrastructure (65), globalization (63)) to 12 highest-ranking end concepts (including (occurrences in parenthesis): animal (108), human (106), water (106), earth (101), mammal (98), psychology (92), philosophy (90), law (86), religion (85), protein (85), science (80), carbon dioxide (80)) and since there is no need to find route from Human to Human and from Water to Water we gained altogether 628 routes of shortest paths between 118 pairs of concepts (our original aim was to take into analysis 10 highest-ranking end concepts like we took 10 highest-ranking start concepts but we took two additional end concepts since we wanted to take such number of end concepts that all concept sharing same ranking position could be taken equally into analysis together). Among routes between 118 pairs of concepts 3 pairs of concepts had shortest paths containing three hyperlinks (on average 58.3 parallel paths between each pair of concepts), 78 pairs of concepts had shortest path containing two hyperlinks (on average 5.3 parallel paths between each pair of concepts) and 37 pairs of concepts had shortest paths containing one hyperlink (on average 1.0 parallel paths between each pair of concepts). All 628 routes contained together 1393 hyperlinks of which 736 were unique.

Table 11.10 shows among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts (hyperlinks occurring 5 or less times are shown in Appendix S due to space constraints).

Based on Table 11.10 Figure 11.3 illustrates among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts when considering only hyperlinks having at least 5 occurrences. Red color indicates 10 highest-ranking start concepts and 12 highest-ranking end concepts (together 20 concepts of which 2 concepts overlapping) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9. Higher width of arrow indicates higher number of occurrences in range of 5–15 occurrences. In Figure 11.3 it appears that 18 concepts of 20 concepts become at least partially connected, only Protein and Psychology remain fully separated.

Table 11.10. Most occurring hyperlinks among 1393 hyperlinks between 118 pairs of concepts.

<i>Hyperlink</i>	<i>Occurrences</i>
mind->life	15
infrastructure->water; mind->evolution	14
energy->carbon dioxide	12
human->mammal; mind->biology; transport->human	11
mind->human	10
animal->carbon dioxide; globalization->carbon dioxide; human->earth; mind->matter; water->human	9
earth->carbon dioxide; food->human; globalization->earth; river->mammal	8
bacteria->carbon dioxide; earth->mammal; human->law; infrastructure->sustainability; mind->taste; water->earth	7
agriculture->carbon dioxide; ecology->carbon dioxide; entertainment->music; human->philosophy; human->religion; infrastructure->transport; mind->conscience; nature->human; nutrition->human; plant->carbon dioxide; water->life;	6
biology->earth; entertainment->writer; horse->mammal; infrastructure->museum; infrastructure->storm; life->animal; life->mammal; nature->science; nutrition->life; pollution->carbon dioxide; transport->carbon dioxide; transport->water; water->carbon dioxide;	5
(25 different hyperlinks, see Appendix S)	4
(61 different hyperlinks, see Appendix S)	3
(159 different hyperlinks, see Appendix S)	2
(444 different hyperlinks, see Appendix S)	1

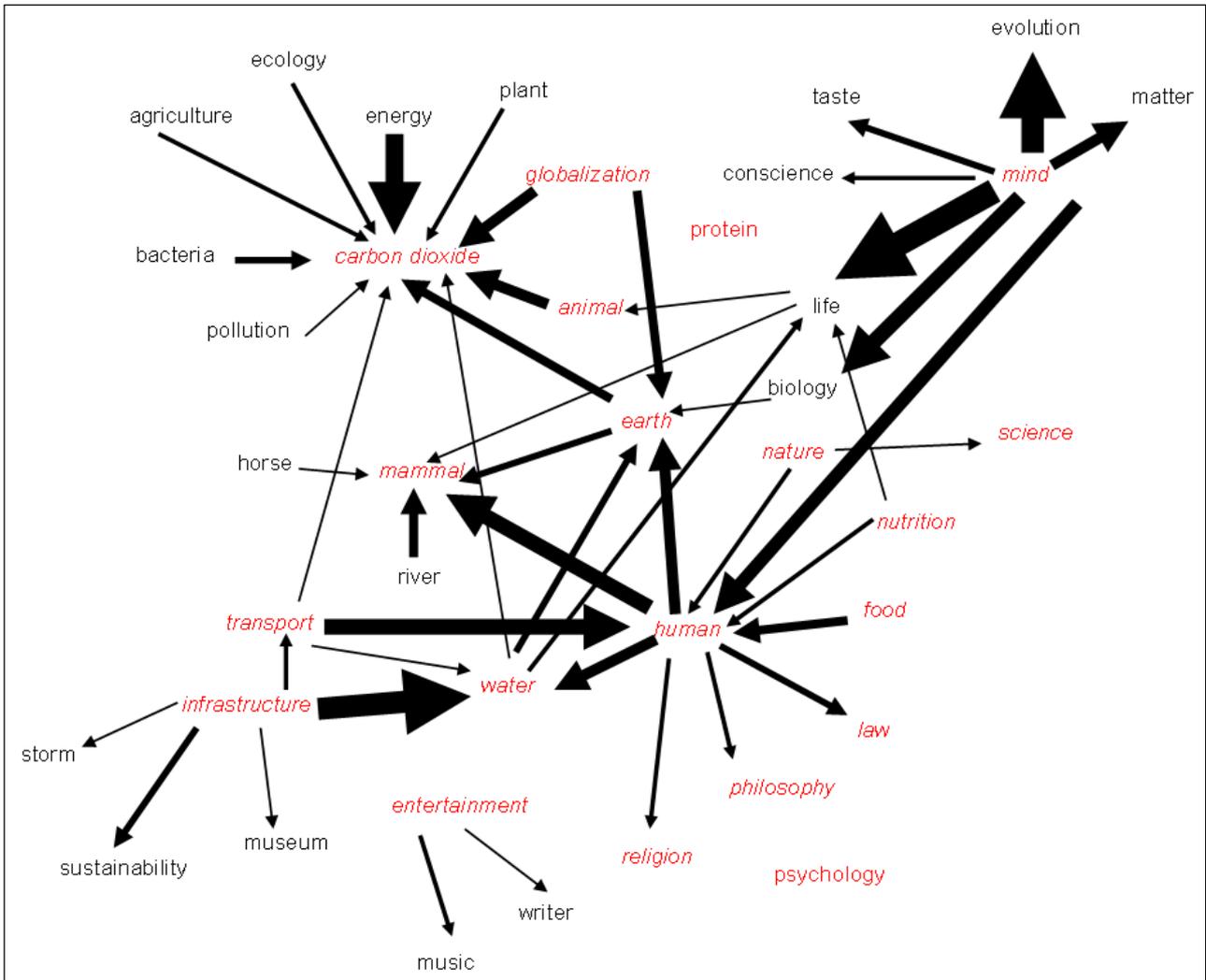


Figure 11.3. Among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts when considering only hyperlinks having at least 5 occurrences. Red color indicates 10 highest-ranking start concepts and 12 highest-ranking end concepts (together 20 concepts of which 2 concepts overlapping) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9. Higher width of arrow indicates higher number of occurrences in range of 5–15 occurrences.

Table 11.11 shows among 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts, and among 736 unique hyperlinks of 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts.

Table 11.11. Among 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts, and among 736 unique hyperlinks of 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts. Number of occurrences shown in parenthesis.

Most occurring concepts among all 1393 hyperlinks			Most occurring concepts among 736 unique hyperlinks of 1393 hyperlinks		
<i>as start/end concept</i>	<i>as start concept</i>	<i>as end concept</i>	<i>as start/end concept</i>	<i>as start concept</i>	<i>as end concept</i>
carbon dioxide (162)	mind (135)	carbon dioxide (159)	carbon dioxide (54)	nature (46)	carbon dioxide (52)
human (142)	infrastructure; nature (83)	mammal (98)	water (53)	mind (39)	earth (40)
mind (138)	human (78)	earth (91)	nature (48)	food; nutrition (34)	water (39)
water (118)	globalization (63)	water (69)	human (44)	infrastructure (33)	mammal (36)
earth (107)	entertainment; food (62)	human (64)	earth (43)	entertainment (32)	animal (31)
mammal (100)	nutrition (59)	animal (54)	mind (40)	human (29)	protein (25)
nature (88)	transport (50)	protein (40)	mammal (37)	globalization (26)	law (23)
infrastructure (83)	water (49)	law; science (36)	food; globalization (35)	transport (20)	psychology (20)
globalization (75)	life (33)	life; philosophy (33)	animal; nutrition (34)	life (16)	science (19)
animal; life (66)	evolution (20)	religion (31)	infrastructure (33)	evolution (14)	philosophy (18)
food (63)	biology (18)	psychology (26)	entertainment (32)	water (14)	religion (16)
entertainment (62)	earth; energy (16)	evolution (20)	protein (25)	biology (10)	human (15)
transport (61)	sustainability (14)	biology (18)	science (24)	matter; sustainability; taste (7)	energy (12)
nutrition (59)	animal (12)	energy (16)	law; transport (23)	music (6)	globalization (9)
science (43)	matter; river (10)	sustainability (14)	psychology (22)	science; writer (5)	bacteria; river (7)
evolution; protein (40)	bacteria; fish (9)	globalization (12)	life (21)		biology; ecology; fish; plant (6)
biology; law; philosophy (36)	oxygen; plant (8)	transport (11)	philosophy (20)		agriculture (5)
religion (34)		matter; river (10)	evolution (18)		
		bacteria (9)			

11.4. Comparison of connectivity of concepts in hyperlink network and co-occurrences in language

We wanted to evaluate how well conceptual connectivity emerging between 20 concepts, consisting of 10 highest-ranking start concepts and 12 highest-ranking end concepts (2 concepts overlapping) in *Wikipedia hyperlinks* connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9, correspond to the highest-ranking co-occurrence of these same *concept pairs in everyday language*. Appendix AC lists all 25153 unique hyperlinks between

3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns.

Conceptual relationships in all 628 routes of shortest paths between 118 pairs of concepts (for our observed set of 20 concepts) containing together *1393 hyperlinks* of which 736 were unique hyperlinks (shown in Appendix S) offered a suitable collection of relationships that we decided to compare to *n-grams* that are a collection of consecutive partially overlapping sequences of *n* words extracted from a text sample of corpus. Thus we retrieved a set of about *one million most frequent 5-grams* (in case sensitive form with part-of-speech tagging, downloaded in October 2013 from http://www.ngrams.info/download_coca.asp) that have been created based on *Corpus of Contemporary American English (COCA)* (N-grams data from the COCA 2013) and we generated listings of the highest-ranking co-occurring nouns for each of our 20 concepts among all about one million most frequent 5-grams of COCA. We identifying co-occurrences for both *singular and plural forms* of nouns and finally combined them so that our results which we report now contain both singular and plural forms even if our notation here uses only singular form of each noun. Table 11.12 shows the number of *co-occurring nouns for each of 20 concepts* among 5-grams of Corpus of Contemporary American English (number of all nouns that can contain more than one occurrence per each noun and number of only unique nouns). Comparing Table 11.12 with Table 11.11 shows quite much difference but for example concerning *five* highest-ranking concepts belonging to *all nouns of co-occurring nouns* and belonging to *start/end concepts among all hyperlinks* both tables share Water and Mind, and concerning five highest-ranking concepts belonging to *only unique nouns of co-occurring nouns* and belonging to *start/end concepts among only unique hyperlinks* both tables share Water and Nature.

Table 11.12 also enables to compare the *number of co-occurring nouns for 20 concepts* among one million most frequent 5-grams of COCA with *number of unique hyperlinks* (either departing hyperlinks in case of being a start concept or arriving hyperlinks in case of being end concept) in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 11.9). This comparison shows that even if distributions and ranking orderings of number of co-occurring nouns and number of hyperlinks have differences for this collection of 20 concepts it seems that average and median values of both co-occurring nouns and hyperlinks have relatively closely shared range. We think that this relatively closely shared range can indicate that coverage of *texts* corresponding to one million most occurring 5-grams have resemblance with coverage that can be reached with *exploration* of hyperlink network of vocabulary A1&A2&B1&B2&C1&C2. However, somewhat higher average and median values for the number of unique hyperlinks (in Table 11.9) than for the number of co-occurring nouns (in Table 11.2) seems to indicate that hyperlink network offers more dense and diverse connectivity than co-occurrence of words in 5-word-long sequences of text and we think that this finding supports suggested earlier mentioned claims that Wikipedia hyperlink network due to its scale-free small-world properties should indeed offer efficient and compact knowledge structure. Anyway it needs to be noted that these average and median values are computed based on concepts that have relatively high ranking in frequency lists of

everyday language and thus possibly have higher values than if computed based on larger and more diverse collection of words.

Table 11.12. The number of co-occurring nouns for each of observed set of 20 concepts among one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from the COCA 2013) showing the number of all nouns that can contain more than one occurrence per each noun and the number of only unique nouns. For each of observed 20 concepts is also shown the number of unique departing hyperlinks as being a start concept and number of unique arriving hyperlinks as being end concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 and sum of these values (sum of number of unique departing hyperlinks as being start concept and number of unique arriving hyperlinks as being end concept).

<i>Concept</i>	Number of co-occurring nouns for current concept in about one million most frequent 5-grams of COCA (all nouns, i.e. can contain more than one occurrence per each noun)		<i>Concept</i>	Number of co-occurring nouns for current concept in about one million most frequent 5-grams of COCA (only unique nouns)	Number of unique departing hyperlinks as being a start concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 11.9)	Number of unique arriving hyperlinks as being end concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 11.9)	Sum of number of unique departing hyperlinks as being start concept and number of unique arriving hyperlinks as being end concept (a hyperlink becomes counted twice if occurring both as departing hyperlink as being start concept and arriving hyperlink as being end concept) in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 11.5)
law	1402		water	263	85	106	191
water	1099		law	254	28*	86	114*
food	632		nature	240	79	33*	112*
mind	561		food	171	93	65*	158
science	552		science	148	50*	80	130
nature	544		mind	128	66	34*	100*
religion	162		religion	62	29*	85	114*
psychology	153		earth	58	33*	101	134
animal	142		animal	51	19*	108	127
earth	114		psychology	40	42*	92	134
carbon dioxide	75		carbon dioxide	26	31*	80	111*
entertainment	64		human	24	121	106	227
human	41		entertainment	23	74	23*	97*
nutrition	39		philosophy	17	42*	90	132
philosophy	38		nutrition	16	68	18*	86*
protein	25		protein	14	14*	85	99*
globalization	17		globalization	11	63	32*	95*
mammal	3		infrastructure	2	65	24*	89*
infrastructure	2		mammal	2	39*	98	137
transport	0		transport	0	72	33*	105*
	average: 283.25			average: 77.5	average: 55.65	average: 68.95	average: 124.6
	median: 94.5			median: 33	median: 56.5	median: 82.5	median: 114

We think that *one million 5-grams* can coarsely correspond to *1000000 words* and with average sentence length below 20 words (DuBay 2004) 1000000 words corresponds to about *50000 sentences*. On the other hand we have, as mentioned earlier, identified that in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 there are *25153 unique hyperlinks* connecting 2878 unique nouns and each of these unique hyperlinks can be expected to have a relation statement (extracted from phrase surrounding hyperlink anchor in article text of start concept) which with average sentence length below 20 words (DuBay 2004) can coarsely correspond to about *503060 words*. Since according to Anderson et al. (Anderson et al. 1988) a student with average score in reading test reads 601000 words per year and with excellent score 4733000 words per year, we think that reading texts corresponding to one million 5-grams can be estimated to require *77–607 days* of school year and somewhat similarly reading texts corresponding to exploration of hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 can be estimated to require about *39–306 days* of school year.

Table 11.13 shows listings of five highest-ranking co-occurring nouns we have generated for each of 20 concepts among one million most frequent 5-grams of COCA (number of co-occurrences of noun mentioned in parenthesis), in case of shared ranking values we have listed all nouns included in five highest-ranking ranking positions.

When comparing *co-occurring nouns of 20 concepts* in Table 11.13 with *hyperlinks having at least 5 occurrences* in shortest paths between 118 pairs of concepts (as shown in Table 11.10 and Figure 11.3) there emerges only very limited overlap including *three pairs of concepts*: animal \bowtie life, carbon dioxide \bowtie water and human \bowtie nature. Therefore we suggest that comparing just the highest-ranking conceptual pairs of hyperlinks with the highest-ranking conceptual pairs of co-occurrences can offer relative limited possibility to identify shared conceptual pairs and thus comparison of conceptual pairs having also lower levels of ranking should be actively compared and paralleled to better identify shared conceptual pairs.

We continued our analysis with still same set of 20 concepts containing 10 highest-ranking start concepts and 12 highest-ranking end concepts (2 concepts overlapping) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9. Now in contrast with Table 11.10 and Figure 11.3 relying on illustrating only hyperlinks having at least 5 occurrences we considered *hyperlinks having at least 1 occurrence*.

We generated Table 11.14 showing overlap that we identified between collection of *1393 hyperlinks* (of which 736 were unique hyperlinks) in the shortest paths between 118 pairs of concepts of our set of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (shown in Appendix S) and concept pairs generated so that each of 20 concepts is paired with all *co-occurring nouns* identified in one million most frequent 5-grams of COCA (N-grams data from COCA 2013). Those hyperlinks that have another hyperlink going into opposite direction in this same table are indicated with an asterisk (*). Five concepts of 20 concepts (Entertainment, Globalization, Infrastructure, Mammal and Transport) did not have any hyperlink of shortest paths to such a noun that would have co-occurred with these concepts among one million most frequent 5-grams of COCA.

Table 11.13. Listings of five highest-ranking co-occurring nouns generated for each of 20 concepts among one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from the COCA 2013), number of co-occurrences of noun mentioned in parenthesis. In the case of shared ranking values all nouns included in five highest-ranking ranking positions are listed.

<i>animal</i>	<i>carbon dioxide</i>	<i>earth</i>	<i>entertainment</i>	<i>food</i>	<i>globalization</i>	<i>human</i>
plant (46)	emission (20)	heaven (12)	news (14)	processor (108)	economy (3)	relationship; resource (5)
species (11)	ton (10)	place (10)	show (10)	store (27)	age; force; impact; world (2)	animal; moon (3)
life (6)	level (9)	face; nation (6)	critic (5)	health (26)	business; context; era; face; process; result (1)	cost; material; nature; rest; role (2)
use (5)	atmosphere (6)	end (5)	industry (4)	water (25)		ability; ancestor; category; difference; environment; fact; foot; majority; place; right; size; species; study; subscale; way (1)
cell; variety (4)	concentration; water (5)	bond; country; people; person; sky (3)	form; world (3)	chain (24)		
<i>infrastructure</i>	<i>law</i>	<i>mammal</i>	<i>mind</i>	<i>nature</i>	<i>nutrition</i>	<i>philosophy</i>
country; destruction (1)	enforcement (118)	bird (2)	heart (57)	law; relationship (20)	professor (8)	professor (11)
	school (112)	species (1)	state (46)	thing (13)	director; food; science (5)	history (7)
	rule (94)		thing (39)	state (12)	department; epidemiology; research; sport (2)	science (3)
	professor (71)		doubt (35)	force; question (11)	activity; fiber; medicine; relationship; school; service; specialist; woman (1)	education; religion; university (2)
	firm (65)		question (28)	study; understanding (10)		degree; department; language; life; music; place; practice; qi; relationship; state; way (1)
<i>protein</i>	<i>psychology</i>	<i>religion</i>	<i>science</i>	<i>transport</i>	<i>water</i>	
source (7)	professor (50)	role (19)	professor (42)	no co-occurring nouns found	glass (68)	
pound (3)	school (15)	freedom (9)	technology (41)		pot (41)	
block; building; gram (2)	department (9)	professor (7)	art (30)		amount (40)	
amount; analysis; body; dna; electrophoresis; form; grain; surface; wheat (1)	course; sport (7)	life; politics; relationship; state (6)	math (21)		cup (30)	
	field (6)	establishment; exercise; study (5)	computer (18)		gallon (28)	

Table 11.14 part 1 of 2 (starts here and continues on next page). Overlap between collection of 1393 hyperlinks (of which 736 were unique hyperlinks) in shortest paths between 118 pairs of concepts of observed set of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 and concept pairs generated so that each of 20 concepts is paired with all co-occurring nouns identified in one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from the COCA 2013).

<i>Current concept (among all observed 20 concepts)</i>	<i>For current concept all co-occurring nouns in one million most frequent 5-grams of COCA that also exist in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (number of occurrences)</i>	<i>Hyperlink in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 that is between current concept and its co-occurring noun (number of occurrences), hyperlinks that have another hyperlink going into opposite direction are supplied with an asterisk (*)</i>
animal	species (11)	species->animal (1)
animal	life (6)	life->animal (5)
animal	habitat (1)	habitat->animal (1)
animal	nature (1)	nature->animal (4)
carbon dioxide	atmosphere (6)	atmosphere->carbon dioxide (3)
carbon dioxide	water (5)	carbon dioxide->water * (1); water->carbon dioxide * (5)
carbon dioxide	gas (2)	gas->carbon dioxide (2)
carbon dioxide	oxygen (2)	oxygen->carbon dioxide (4)
carbon dioxide	carbon (1)	carbon->carbon dioxide (2)
earth	life (1)	life->earth (3)
entertainment	no shared hyperlinks and co-occurrences	
food	nutrition (5)	nutrition->food (1)
food	salt (3)	food->salt (1)
food	sugar (2)	food->sugar (1)
food	butter (1)	food->butter (1)
food	energy (1)	food->energy (2)
food	soup (1)	food->soup (1)
globalization	no shared hyperlinks and co-occurrences	
human	nature (2)	nature->human (6)
human	species (1)	human->species (1)
infrastructure	no shared hyperlinks and co-occurrences	
law	institution (5)	institution->law (1)
law	tax (4)	tax->law (2)
law	college (3)	college->law (1)
law	crime (2)	crime->law (1)
law	spirit (2)	spirit->law (1)
law	democracy (1)	democracy->law (1)
mammal	no shared hyperlinks and co-occurrences	
mind	body (19)	mind->body (2)
mind	life (6)	mind->life (15)
mind	nature (3)	nature->mind (3)
mind	spirit (2)	mind->spirit (2)
mind	evolution (1)	mind->evolution (14)
mind	idea (1)	mind->idea (1)
mind	matter (1)	mind->matter (9)
nature	life (6)	nature->life (3)
nature	science (6)	nature->science (5)
nature	mind (3)	nature->mind (3)
nature	art (2)	nature->art (1)
nature	human (2)	nature->human (6)
nature	matter (2)	nature->matter (1)
nature	animal (1)	nature->animal (4)
nature	consciousness (1)	nature->consciousness (2)
nature	evolution (1)	nature->evolution (2)
nature	phenomenon (1)	nature->phenomenon (1)

Table 11.14 part 2 of 2 (started on previous page and continues here).

<i>Current concept (among all observed 20 concepts)</i>	<i>For current concept all co-occurring nouns in one million most frequent 5-grams of COCA that also exist in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (number of occurrences)</i>	<i>Hyperlink in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 that is between current concept and its co-occurring noun (number of occurrences), hyperlinks that have another hyperlink going into opposite direction are supplied with an asterisk (*)</i>
nutrition	food (5)	nutrition->food (1)
nutrition	science (5)	nutrition->science (3)
philosophy	science (3)	science->philosophy (2)
philosophy	education (2)	education->philosophy (2)
philosophy	life (1)	life->philosophy (3)
protein	dna (1)	dna->protein (1)
psychology	education (2)	education->psychology (2)
psychology	science (1)	science->psychology (1)
religion	life (6)	life->religion (3)
religion	science (3)	religion->science * (1); science->religion * (2)
religion	society (1)	society->religion (1)
religion	university (1)	university->religion (1)
science	technology (41)	technology->science (2)
science	university (8)	university->science (1)
science	education (7)	education->science (2)
science	nature (6)	nature->science (5)
science	nutrition (5)	nutrition->science (3)
science	philosophy (3)	science->philosophy (2)
science	religion (3)	science->religion * (2); religion->science * (1)
science	knowledge (1)	knowledge->science (1)
science	psychology (1)	science->psychology (1)
transport	no co-occurring nouns for concept "transport"	
water	ice (26)	ice->water (1)
water	blood (6)	blood->water (1)
water	fish (5)	water->fish (3)
water	river (5)	water->river * (2); river->water * (2)
water	ocean (4)	ocean->water (1)
water	salt (4)	salt->water (1)
water	sugar (4)	sugar->water (1)
water	oxygen (2)	oxygen->water (1)
water	desert (1)	water->desert (2)
water	plant (1)	plant->water (2)

Now based on results of Table 11.14 it appears that a promising amount of overlap emerges between hyperlinks in *the shortest paths* between 118 pairs of concepts and *co-occurring nouns* of 20 concepts. We think that this relatively high level of overlap gives convincing support to suggest that a student's explorations in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 can be considered to offer such *natural connectivity* of concepts that resembles connectivity existing in large corpus of natural language. Anyway, it is interesting to note some differences in emphasis so that among shared hyperlinks and co-occurrences the highest-ranking hyperlinks include mind -> life (15 occurrences), mind -> evolution (14 occurrences) and mind -> matter (9 occurrences), whereas the highest-ranking co-occurring nouns include conceptual pairs technology \bowtie science (41 occurrences), ice \bowtie water (26 occurrences) and mind \bowtie body (19 occurrences).

Based on Table 11.14 we generated Figure 11.4 illustrating overlap that we identified between collection of 1393 hyperlinks (of which 736 were unique hyperlinks) in the shortest paths between 118 pairs of concepts of our set of 20 concepts in

hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (shown in Appendix S) and concept pairs generated so that each of 20 concepts is paired with all co-occurring nouns identified in one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from COCA 2013).

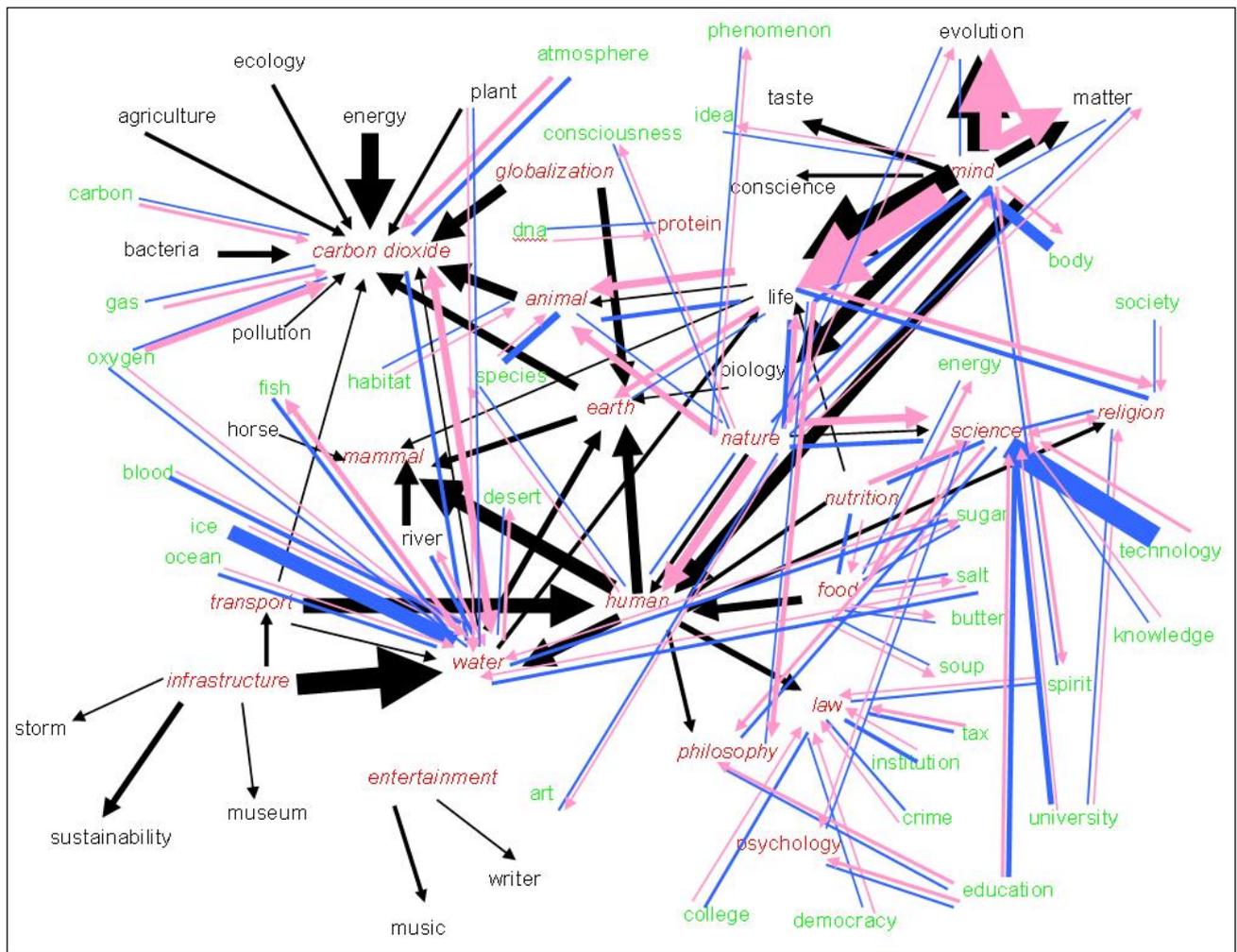


Figure 11.4. Overlap between collection of 1393 hyperlinks (of which 736 were unique hyperlinks) in the shortest paths between 118 pairs of concepts of our set of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (shown in Appendix S) and concept pairs generated so that each of 20 concepts is paired with all co-occurring nouns identified in one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from COCA 2013). The set of original 20 concepts are shown with red font and black arrows illustrate among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts when considering only hyperlinks having at least 5 occurrences, hyperlinked concepts supplementing original 20 concepts shown with black font, and higher width of arrow indicates higher number of occurrences in range of 5–15 occurrences (as in Figure 11.3). In contrast with Figure 11.3, now Figure 11.4 extends to show hyperlinks having at least 1 occurrence and this introduces supplementing concepts shown with green font. When a hyperlink of the shortest paths has overlap with co-occurrence of same pair of concepts in one million most frequent 5-grams of COCA this hyperlink is shown with a new pink arrow and co-occurrence is shown with a new blue connecting line, now higher width of arrow or line indicates higher number of occurrences in range of 1–15 occurrences (so please note that even if this range of width 1–15 is visualized with same range of absolute units on paper as for black arrows, this range is defined based on 1–15 occurrences whereas for black arrows it is defined based on 5–15 occurrences). For those shown hyperlinks that have another hyperlink going into opposite direction the higher one of two available arrow widths is shown.

Chapter 12. Concluding remarks

We have proposed new computational methods to support personalized learning with collectively created educational resources and to explore human-built knowledge structures for various tailored pedagogic purposes. We hope that the proposed methods can be pointing direction towards fertile inspiring new ways to foster learning and aid challenged learners.²⁵ It is also evident that some innovations can help a greater population than some others but on the other hand smaller populations can sometimes have much greater need for the innovation (for example persons belonging to minorities that have a specific special need). For example among people with special needs, such as impaired people, new innovations can open totally new ways to express oneself and thus innovations directed to them can revolutionize everyday life much more than some other innovations directed to ordinary people and providing just minor change in living habits. In fact we think that when developing educational technology, the people with special needs should be among primary targeted user groups since they appear to benefit most from even relatively simple innovations and they have strong need for new solutions enhancing independent management of life.

12.1. Supporting intuitive and flexible forms of learning

In our research we have identified a strong need to enable learners to *create and explore knowledge* in relatively unconstrained and easily expandable form. Also it seems that enabling supporting compact ways to illustrate knowledge is important. There are many ways to approach same single piece of knowledge and position it in a wider entity. It seems that in traditional school environment the local community and culture typically give some motivation for having *shared and complementing perspectives* among learners and their teacher during learning sessions. For example the geographical location and the country's history can give strong influence on how surrounding world is typically perceived and understood. The cultural background can easily influence education about learning topics concerning social and humanistic issues but also learning topics related to natural science like mathematics and physics, since teaching needs concrete examples that typically use such objects found in the current cultural environment (for example indicating how urban or rural the environment is and what kind of climate is dominating).

²⁵ Especially in engineering and technology related fields of research we are inherently dealing with constantly evolving process of computer systems, user interfaces, sensors etc. and thus many new ideas and solutions will quickly become obsolete and old-fashioned. Only much later in historical perspective it can be more clearly evaluated what initiatives have had a positive long-lasting effect for the development.

We have developed and evaluated experimentally computational methods dealing with recommendation of *fruitful learning paths*, networks of paths and even greater entities. We think that a related area that deserves attention in further research is about *prediction of the learners initiatives*. It seems for us that current state of research about computer-supported learning and also our work has strongly focused on suggesting promising resources based on the current position and path in the knowledge network but there is a need to extend analysis to what is predictable based on the learner's prior activities and the patterns observed in activities of sufficiently statistically reliably large population samples. One important issue is also to develop methods to make *synthesis about the learner's progress* in learning so far and how overlapping entities of knowledge and overlapping (possibly conflicting) perspectives can be taken into account.

We think that many interesting *cultural perspectives* could be addressed by methods similar to the methods we proposed by extending analysis to various *language versions* of the Wikipedia and their similarities and differences. However, it needs to be cautious in comparison since it is hard to identify if some language versions have been generated independently from the main language versions or not (since there is often a temptation to copy from the most covering extensive article to other translations) and if they are written by someone really who has grown up in the typical culture of that language. Furthermore for example Spanish and French are used in a diversity of large populations in cultural locations around the world thus making generalizations hard. If privacy issues can be sufficiently addressed, perhaps *tracking the geographical region* for each edit and retrieval of an article could offer help to distinguish specific cultural patterns of Wikipedia content that can then support learning with diverse cultural perspectives.

Educational solutions relying on the Wikipedia, or other wiki based encyclopedias, face challenges that include *vandalism* and contributions that intentionally or unintentionally introduce unrelated, false, commercially promoting or copy-righted material. We think that popular articles and articles dealing with complex and sensitive issues may give a specific interest for people seeking attention to make provocative and vandalous edits. Thus when managing education of children and there is strong need to support learning correct facts right from the start there is can be a unpleasant risk of being misinformed and offended by manipulated content in the Wikipedia. Thus even when exploring very basic vocabulary there is a risk to be exposed to unsuitable material and only one single false edit is enough to cause this. Articles receiving a lot of vandalous edits get very high edit counts that can misleadingly give an impression that these articles have been ambitiously developed thus biasing usefulness of edit count as an indicator of article quality.

It is also educationally challenging that actually many of the most fundamental and popular topics concerning life and world often have so much *conflicting schools of thought* and sensitive or controversial themes that the freely edited encyclopedic articles can suffer from heavy edit wars thus weakening the opportunities to get an objective viewpoint for learning. These topics include for example sex, religion, human races, wars, ethnic conflicts, territorial disputes, evolution theory, animal rights, imperialism

and colonization. So even though it is especially important for students to learn about these fundamental topics and gain critical objective and analytical understanding of them to promote civilized and peaceful living, the freely editable learning content remains vulnerable for bias and provoking unnecessary prejudice and conflicts. There remains a need to develop methods to track and indicate to learners and educators those articles that seem to contain highly misleading and excessively subjective coverage about complex controversial topics.

Afterwards when evaluating our research reported in consecutive publications [P1]-[P8] there seems to emerge a trend of *progressively changing focus*. We think that while in the first publications we give relatively much emphasis on developing practical technology enabling students to use concept maps to synthesize collaborative work and to represent a student's exploration in hyperlink network of the Wikipedia, then in later publications we represent methodology that is not necessarily so much relying on using concept maps per se or visualizing learning process but instead seems to emphasize developing general modeling of human thinking and language structure on relatively abstract level. We hope that this changing focus can possibly offer additional perspectives to many challenging characteristics concerning developing computational methods that aim to represent educational material with conceptual networks and to offer suitable kind of guidance and inspiration for a student to adopt new knowledge.

One general challenge is that basic *concept maps* that we have decided to use to represent knowledge structures do not enable easy ways to visualize some *relational aspects of knowledge*. For example links depicting relations can become messy especially if they are intended to be only linear, and if they are allowed to be curvy they require cumbersome following of the line. Thus using concept maps seems to require making hard decisions between alternative layouts of concepts and prioritization which concepts get more optimally visualized links depicting relations. With weakly motivated layout decisions some concepts may get prioritization without actually deserving it. Also links denoting that some concepts belong to greater entity (or to even nested hierarchies) are difficult to visualize especially if several concepts belong to several different entities. We think that there is a need for research to better understand how conceptual relations can be fruitfully indicated in concept maps with for example colour coding, dotting, font size, font effects, various shapes of bubbles/squares and even animation.

In contrast with many previous proposals in the field of computer science and education, in our research we have not only developed new methods for knowledge management but also implemented *functional prototypes* that can be used in various educational contexts for many pedagogical purposes. In addition we have carried out various *empirical experiments* in real education setting to test our self designed and implemented software prototypes and to model characteristics of learning with conceptual networks. We do not know any previous research that has created similar results as our work especially concerning educational use of such cumulative and explorable knowledge structures that we have generated based on Wikipedia online encyclopedia.

We think that the Wikipedia can offer useful ways to model *human thinking* and language structures that can be exploited in knowledge adoption with cumulatively growing vocabularies and cumulatively growing conceptual networks relying on hyperlink network between concepts of the vocabulary. However to be applicable for representing and supporting vocabulary adoption of a growing child one challenge is for example that the hyperlink network of the Wikipedia that is used to connect concepts of vocabulary is actually largely created to represent an *adult perspective* in both selection of concepts that have been included into the encyclopedia (i.e. supported article topics, writing style and formatting of articles) and selections made when hyperlink network has been built (i.e. what words in the article text deserve to become hyperlink anchors and thus hyperlinked by Wikipedia editors) .

12.2. Some prospects concerning proposed methods

In publications [P1]-[P8] we have proposed various methods. These methods aim to support collaborative learning and guided exploration in hyperlink network of the Wikipedia as well as building concept map structures. These methods also aim to support adoption of vocabulary and new knowledge following principles of spaced learning and relying on efficient scale-free small-world networks and exploiting collaboratively edited knowledge of Wikipedia online encyclopedia. In the following we try to briefly conclude some features we consider essential for these proposed methods and mention some aspects that we think could be considered in future work.

In publication [P1] we proposed a new educational framework (that we referred to as a collaborative learning platform) to assist *learning conceptual structures* in a *collaborative environment* both online and offline, and we have implemented a prototype enabling collaborative ideation to build shared concept maps representing conceptualization of learners. To support exploitation of the specific complementing strengths of each collaborator we proposed that a educational framework (a collaborative learning platform) monitors activity patterns of each collaborator role based on Competing Values Framework and if they differ sufficiently from the expected activity profiles the system asks the representatives of this role to adjust that activity to follow the expected profile.

In the future, the guidance could be extended to cover various aspects of ideation. The system could offer personal advice *how to communicate* most productively in the current context. This could deal with group cohesion, timing, goal-orientation and distribution of tasks. Guidance could also help to elaborate other's ideas and to give feedback about them. The system could tell if immediate or postponed criticism would be needed to maintain fertile ideation process.

In the proposed method guidance for collaboration generated by the educational framework (collaborative learning platform) is based solely on the *activity patterns of collaboration* and thus collaborators are expected to be responsible about the factual content of shared knowledge. We think that this design decision fruitfully enables to avoid computational complexity and on the other hand enables to have knowledge

management process to be carried out by the collaborators in natural form. Thus we do not expect the system to be necessarily able to evaluate ideas itself using text analysis although it would be useful and advanced computational models should be developed for that purpose as well. Furthermore, *forming synthesis* and finding mutual agreement of ideas could be assisted by proposals initiated by the system when certain collaboration patterns indicate that time is right for that. Naturally the proposed collaborative method can be supplied with external knowledge structures like generating concept maps based on hyperlink network of the Wikipedia as we proposed in publication [P2].

Present theories concerning the principles dictating the personality and collaboration are still ambiguous and thus it can be advisable not to get too fixated on any single theory that tries to explain processes of learning and collaboration. For example *neuroscience* accompanied with *computational simulations* can possibly relatively soon verify some theories of human thinking and to disqualify some others. Thus, for time being it might be important to focus research efforts on general techniques that could hopefully be applicable what ever specific theories prove to be valid in the long run. A breakthrough in collaboration theories might also come from finding new kind of *transformations or mappings* between individual patterns of ideation. Besides ideation, collaboration practices need to be explored on even wider scale. For example, domains of creative problem solving, problem-based learning and decision making can offer useful application areas for new innovative collaborative methods and educational frameworks.

In publication [P2] we proposed a new method for *guided generation of concept maps* from open access online knowledge available in *Wikipedia online encyclopedia*. The method extracts semantic relations from sentences surrounding hyperlinks in the Wikipedia's articles and lets a learner to create customized learning objects in real-time based on collaborative recommendations considering her earlier knowledge. Wikipedia articles and interconnecting hyperlinks define conceptual relationships which can be explored by the learner thus forming learning paths and building concept maps representing his conceptualization.

In the proposed method learning efforts become well documented and the produced *visualizations* can be easily reused, updated and shared. By tracking the building process of concept maps, teachers can practically evaluate learning progress in respect to learner's individual resources. The method also enables teachers to update their own knowledge and plan curriculum.

By analysing the temporal construction phases of a concept map can assist identifying and responding to various *learning styles*. With small modifications the method could be transformed to generate automatically concept maps for school lessons with a great variation and always up-to-date. These concept maps could be tailored to address varying topics and learning styles of each attending learner. Extending the method to *parallel language versions* of the Wikipedia or other wikis could enable new ways to understand cultural and language related differences in conception and ontologies. In addition, learning foreign languages could be supported with comparison

of conceptual relations simultaneously in two language versions. Furthermore, in *special education* and assistive tools various everyday processes could be illustrated.

The method can supply information retrieval and question answering with close personalized touch. A great diversity of easily digestible pieces of knowledge can be provided to the learner with the method. Even if the learner is challenged in her cognitive skills, the method still guarantees her rights to make the ultimate decisions about the learning path to proceed.

Besides text, the concept maps could be easily transformed to exploit *multimedia content*. In addition, various metrics could be applied to assist the learner to identify the most mature and trusted content in the online knowledge resource. Thus the method could promote using the most extensive and reliable learning paths. In this respect some possible methods to generate alternative exploration paths are proposed in publications [P3] and [P4] to exploit article statistics and topology and evolution of hyperlinks.

Even if the method occasionally provides inaccurate knowledge it can be exploited as a learning resource that urges the learner to critically evaluate the content and make rephrasing that is well mapped to her previous conception. Incomplete explanation phrases offered to support building concept maps can be considered as a valuable way *to activate the learner* to excel oneself in personal knowledge acquisition and formulation. Completing the phrases can be used as a personalized exercise to evaluate learning progress so far. The learner becomes actively encouraged to rephrase the relations suggested by the method so that they fully correspond to her own intuition. In contrast with many other research proposals in this field, we have implemented a fully functional prototype and with experiments verified the success of our proposed method.

We think that too often educational practices rely on unverified beliefs. We want to actively promote bringing theoretical research results into everyday school environment to increase productivity and quality of life. Due to *modular structure*, the functionality of our method can be flexibly extended and modified later to exploit new better modules following the latest pedagogical insight. We also think that the patterns of learning emerging in school life should be exploited much more to develop new theoretical models. The proposed method and the related prototype indicate new possibilities to facilitate *tracking learning events* at schools to find better models to support learning. Long-term studies with large populations are needed to better understand the long-lasting and slowly evolving learning processes in individual minds. It is possible that earlier research has too optimistically aimed at single models that could favourably support different learners. We think that the proposed method can give directions for new *learning practices that evolve* and mature together with each individual learner. For example, curriculum and learning objects may often be too fixed and aimed at an average learner only. To liberate education from too homogenous one-for-all standards we need to cope with challenges of identifying the great variety in the learning progresses of individuals. To really address all learning difficulties it is a necessity to take into account different personalities, temperaments and interaction styles acquired during the early childhood. Increasing personal knowledge and educational level should be seen as an important goal for everyone, affecting only positively to well-being.

We think that the proposed method offers practices to be considered as mediators to enhance understanding individual *learning styles* and how they are related to *educational needs*. To capture the essence of the holistic learning process performed by an individual mind requires new analytical approach that should increasingly exploit latest technology, such as information networks, mobile communication and virtual teams. In school, the educational practices should aim to provide *life-long learning skills* not only based on today's requirements but also trying to predict tomorrow's requirements. To stay in the first wave, it is important to model how new knowledge can be submerged with prior knowledge and how rich *adaptive representations* can support this process. One possible way to address these needs is proposed in publication [P6] that presents an educational concept mapping method based on high-frequency words and Wikipedia linkage.

We think that learner-driven *unconstrained experimenting* with various conceptual structures can be a key factor in the development of new advanced support tools. It seems to us that extensive indexing of knowledge from online resources before a learning process has even started cannot fully satisfy the individual needs of a learner. We think that the learner should get thoughtful guidance but eventually to be free to make creative initiatives following her intuition. We think that exploration patterns should be well documented so that they could be directly exploited in building *collective knowledge structures*, beneficial for other learners later as well. One possible way to address these needs is proposed in publication [P5] that presents a collaborative framework for agglomerating pedagogical knowledge with concept maps. Along the years, learning process of an individual should produce conceptual structures that illustrate her *core understanding*, like an autobiography in a form of a visualized relational database.

We aim to develop further the pedagogical advantages of our proposed method. The method can be extended to retrieve automatically concept maps about a wide range of topics to provide *ready-made learning objects*. These concept maps could be used as an augmented user interface for browsing the Wikipedia. Even in offline mode the concept maps could serve as a *compact search tool* representing conceptual relations since many fundamental facts are fixed and do not change daily. With a shared educational framework (collaborative learning platform) individuals could use the methodology both online and offline to build *mutually agreed concept maps*. This should support constructive dialogue to find resolution ensuring that all opinions become heard.

We think that it is important that our method supports drawing concept maps even without retrieving knowledge from the Wikipedia. In the case that the Wikipedia is temporarily inaccessible or it provides irrelevant or false information it is important that the user can freely decide the structure and labelling of the concept map. We think that the proposed method shows how important it is to support free exploration in conceptual spaces and recognize many equally valid *alternative conceptions*. We think that learning through trial and error can well support iteratively refining processes of human thinking.

Future research should give attention to modelling how the construction of pedagogically favourable concept maps really relies on the features of *unrestricted*

exploration. Thus there is a need to explain how the learner actually can benefit from experimenting with the keywords of a learning topic in a concept map following her intuition. Recommendable practices of knowledge management should be identified and used for developing new adaptive tools that support learning, innovation and creative problem solving. Domain-independent methods to explore knowledge and represent it illustratively should have a high priority in the research agenda.

In publication [P3] we proposed a new semi-automated method for generating *personalized learning paths* from the Wikipedia online encyclopedia by following *inter-article hyperlink chains* based on various rankings that are retrieved from the *statistics of the articles*. Alternative perspectives for learning topics are achieved based on hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate, editing rate, or user-defined weighted mixture of them all enabling the learner to build independently concept maps following her needs and consideration.

In publication [P4] we proposed a new method to support educational exploration in the hyperlink network of the Wikipedia online encyclopedia and extending the method introduced in publication P3. Method of publication of [P4] extends method of publication [P3] in respect to three important new features: the learner can simultaneously operate with *parallel ranking lists* of hyperlinks, the concept map construction emphasizes building diversely *branching structures*, and different consecutive *temporal versions* of Wikipedia articles can be browsed.

Since methods of publication [P3] and [P4] are closely related in the following we try to discuss about them together and thus we try to conclude some features and future prospects we consider central for such a method that supports generation of personalized learning paths based on Wikipedia article statistics as well as topology and evolution of hyperlinks in the Wikipedia.

We have evaluated *ranking hyperlinks* of the article in respect to five different features based on article statistics and we think that these features can be considered to correspond to a set of fruitfully complementing different characteristics of knowledge structures of the Wikipedia. In our experiments we found distinctive ways to differentiate exploration of hyperlinks based on the features preferred by the learner. Using various rankings it is thus possible to provide *alternative perspectives* to knowledge and thus enable the learners to build independently favourable learning paths following their personal needs at the moment.

Concepts belonging to various domains of life and to various abstraction levels in a certain topic have obviously different tendencies to support the proposed five statistical features. Also, features can have many *hidden correlations* that should be taken into account for a balanced use of statistics. High editing rate typically produces high article size. Typically each single event of editing article increases also viewing rate if the editor wants to check the finished version of article after editing. When building learning paths, our proposed method possibly too optimistically expects high relation between all consecutive concepts in a *traversed chain of hyperlinks*. Hyperlinks of an article can point to target articles that deal with topics that are opposite or ambiguous to the title of current article. Unfortunately, it is hard to develop general methods that could reliably identify the exact type of relation between target article and current

article. Extracting relation statements from the sentence surrounding the hyperlink can also be troublesome since often the sentence does not explicitly define the relationship between the title of current article and the title of target article, but instead describe something else.

When building learning paths, a major challenge for semantic continuity is that some measures based on the *characteristics of target article* may not indicate well the *actual relatedness* between current article and target article. For example, if ranking of hyperlinks is based on viewing rate, the target article having the highest viewing rate is prioritized. But this viewing rate consists of a great variety of visits arriving to the target article through various hyperlinks, not only from current article. Thus, viewing rates describe just the overall distribution of visits to individual Wikipedia articles and fail to tell how the preference to visit a certain target article varies depending on the current article.

The method could also somehow take advantage of the fact that typically many changes in an article are performed in bursts, for example after related news has been published in the media. Various *navigational aids* have been introduced to the layout of Wikipedia articles, for example category tags, “See also” section, navboxes and infoboxes. Also redirects, disambiguation pages and “What links here” queries assist finding related articles. However, we argue that these assistive functions complementing each other cannot clearly recommend the most promising hyperlinks for further exploration. To increase efficiency of exploration and to ensure finding the most relevant hyperlinks, there is a need for intuitive visualization of *adaptive ranking* of hyperlinks of the current article.

There are limitations with the current method especially since it was purposefully designed to be simple and *computationally easy*. The statistical features used with the method could be chosen in various alternative ways. If the online services we suggested to be used for querying statistics should become shut down it still remains possible to retrieve *statistics with alternative implementations*.

Since a lot of articles of the Wikipedia present facts that have a low probability to become constantly updated or seriously questioned, we think that our method could be successfully used also *offline*. Despite of its huge coverage, the plain textual content of English language version of Wikipedia can be stored locally in *one compressed file* that can be estimated to require storage space about ten gigabytes as of June 2013. The method might use also the article statistics from just off-line sources. We suggest that already the current knowledge structures of the Wikipedia and statistics available so far can enable creating relatively reliable ranking of hyperlinks that reflects *conception of global community*. Relying on off-line content would enable using the method with very low computational costs and minimal delay.

Traversing just a short chain of hyperlinks in the Wikipedia can enable to encounter essential educational knowledge about a desired topic, but it is hard to define requirements for an *optimal exploration path*. Generation of recommendable exploration paths to the learner should can be favorably personalized in diverse contexts and to be reached with limited computational load. It seems that desired *educational perspectives* can be efficiently offered to the learner by chaining ranked hyperlinks that

have correlation between a *simple statistical feature* of both current article and target article.

It is possible to explore just the relations between the *latest versions of articles*. On the other hand, browsing *consecutive temporal versions* of an article offers alternative insight by showing emergence of knowledge clusters. Using these two parallel approaches should enable the learner to gain complementing ways to process and adopt knowledge. To let the learner *emphasize earlier knowledge or definitions* in her browsing experience, we have suggested that the generation of recommended exploration paths can favor hyperlinks having previously encountered target articles or hyperlinks belonging to the introduction section of current article.

The proposed method and experiment have indicated a promising unexplored area for research concerning new methodology to adaptively explore the knowledge space of the Wikipedia. We suggest that the method we have developed for the Wikipedia can be relatively well applied to also other *collaborative knowledge management environments* and even intellectual mental processes in human mind.

In the future research there is a strong need for further classifying various features that can be used in ranking of hyperlinks that connect concepts (or articles). It can be possible to identify individual most favourable *features for each domain* of knowledge. These specific features could enable exploring knowledge in most coherent manner taking into account special characteristics that are typical for this domain. It is also important to develop methods that can address individual *characteristics of every learner*. For each learner it could be identified what are the features that need to be used in ranking of hyperlinks to fulfil his special personal needs. For example, preferred learning style, personality and hobbies of the learner could be considered when setting the ranking criteria that affect which hyperlinks become promoted to the learner. Furthermore, it would be advantageous that the learner could himself make adaptively consistent decisions about what features to prioritize in ranking when exploring varying learning contexts. In many cases, *user-defined ranking criteria* should not probably support just one perspective but instead to be a dynamic weighted mixture of them all.

In addition, it is important to develop advanced but still computationally sustainable analysis methods that help to rank alternative hyperlinks and thus to find most promising learning paths. It is important to have such analysis methods that are not dependent on any proprietary online service. To effectively develop and ensure automated knowledge management it is important to support *open access knowledge bases* and *open source modules*. Interfaces should be kept as interoperable and standardized as possible to best promote updating individual components of modular applications or replacing them with alternatives. Knowledge management tools should be actively introduced for using them in *ordinary everyday life* for example in education, problem solving, decision making, design and innovation. Research should emphasize access for all since knowledge tools are often most crucial for people with special needs. The efforts should aim at providing a better quality of life and letting the learner to excel oneself and follow his personal interests.

In publication [P5] we proposed a new educational framework, *ConceptMapWiki*, that is a wiki representing pedagogical knowledge with a *collection of concept maps*

which is collaboratively created, edited and browsed. The learners and educators provide complementing contribution to *evolving shared knowledge structures* stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria. Pedagogically motivated learning paths can be collaboratively defined and evaluated, and educational games can be incorporated based on browsing and editing concept maps.

We think that knowledge structures and user logs gathered with the method can be exploited in daily educational work for *evaluating learning progress* of students, modeling collaborative learning processes and identifying patterns of successful learning. The method could be easily augmented with such educationally useful components that resemble those that have been developed for traditional wikis, data mining and clustering algorithms.

The method could automatically suggest which concept maps most urgently need refinement and recommend *promising learning paths* based on concept maps having popular browsing patterns and active edit histories. Simple tentative concept maps and supplementing hyperlinks could be automatically generated based on *hyperlink network of the Wikipedia*. In addition, the method might help in curriculum planning and developing semantic analysis and building ontology models. There is a need for comparative research to evaluate benefits of alternative wiki technologies and ontology models and to synthesize their methodologies to develop general theory for creative problem solving and pedagogical guidance in computer-assisted learning.

In publication [P6] we proposed a new computational method to support the learner's *knowledge adoption* based on concept mapping relying on *three perspectives*: learner's knowledge, learning context and learning objective. Each perspective is represented by a learning concept network that is generated based on a set of *high-frequency words* from a representative text sample that are connected based on the *shortest hyperlink chains* between corresponding *Wikipedia articles*. The learner explores ranking-based routings connecting learning concept networks by expanding a concept map.

To keep our method computationally and pedagogically fluent and transparent, we used relatively simple criteria to form a *learning concept network* by connecting high-frequency concepts in text samples based on the shortest hyperlink chains between corresponding Wikipedia articles. As an alternative and supplementing the Wikipedia linkage the shortest paths can be retrieved from a collection of *concept maps drawn by learners*. The proposed method is independent from any service provider since collections of vocabularies, conceptual relationships and shortest paths in conceptual networks can be generated with *various alternative resources*. Besides retrieving learning objectives from Wikipedia articles, the method can be also applied to explore directly concept maps drawn by teacher and learners, to support reaching complementing consensus.

The current model based on learner's knowledge, learning context and learning objective could be augmented with components addressing for example types of personality, community and education. *Concept ranking* and *hyperlink ranking* schemes could take into account desired semantic relatedness measures and maturing of the

Wikipedia. High-frequency concept lists and rules of conceptual chaining could be modified according to personal needs. To assure pedagogic gain, quality of text samples used to generate learning concept networks and exploration patterns of students could be socially annotated. Besides nouns, other conceptual classes could increase the pedagogic and expressive value of the method.

Since *small-world networks* seem to bind brain functions and the Wikipedia (and also *scale-free properties* identified in the Wikipedia possibly have correspondence in brain functions), we suggest developing related models for educational tools. Besides the Wikipedia, we expect our method to be applicable to other small-world networks, such as wikis, the World Wide Web or even real-life social networks at schools. The learner could have different learning context networks defined for different *school activities, collaborator roles, educational levels* and so on. By comparing how different learners rely on contextual recommendations one could identify common *learning challenges* and match collaborators best complementing each other. Extensive further research and experiments in real educational setting are needed to augment models and make pedagogically verified support tools. Since literacy is a crucial for self-sustained development for all children, we hope that future research can develop powerful sequential models for guiding the learner's exploration with any context and objective to balanced adoption of new knowledge.

In publication [P7] we proposed a new educational framework relying on *pedagogic conceptual network* generated by linking the most essential concepts of learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary. To *adopt vocabulary* the learner traverses links of pedagogic conceptual network along learning path generated by method in sequential process having tailored variation and repetition computed based on theory of *spaced learning*. The learning path is shown to learner as sequence of compact relation statements extracted from sentences surrounding hyperlinks in Wikipedia articles, supplied with set of visualizations based on main verb identified in them.

In the proposed framework exploration in hyperlink network is affected by various *adjustable parameters*. Based on learner's needs and teacher's advice or earlier testing, learner manually sets nine parameters including session vocabulary size, degree of new content, session duration, learning speed, degree of required adoption, degree of exposure repetition, degree of retention repetition, interval of exposures and interval of retentions. When starting new learning session method first evaluates learner's initial *conceptualization level* based on recall about shown sample of concepts how they are linked, and the method supplies each concept of pedagogic conceptual network with a value representing measure of adoption.

For each concept, the framework keeps a record and *updates five values*. Besides measure of adoption, they include measure of exposure repetitions (number of spaced exposures of the concept so far), measure of retention repetitions (number of spaced retentions of the concept so far), time between exposures (average time between spaced exposures of the concept so far) and time between retentions (average time between spaced retentions of the concept so far). At each step of proceeding to next concept along learning path, all five values of that concept are updated.

When generating learning path, the framework primarily guides learner to traverse in pedagogic conceptual network at each step from current concept next to a concept having now the *lowest measure of adoption*, along the *shortest connecting hyperlink chain*. As a part of the research we experimentally generated a variety of pedagogic conceptual networks for selected learning topic vocabularies encountered often in educational setting addressing diverse combination of characteristics of a learner.

Future work should heavily invest in rapid agile prototyping with diverse populations of learners in versatile real educational settings to gather large quantities of behavioral data for fine-tuned modeling of intuitive *personalized learning practices* when learners adopt vocabulary and new knowledge. With increasing penetration of smart phones and tablets through whole society we are living a critical period when the educational market becomes shared with long-lasting dominance by most innovative solutions and public education faces risks to become locked-in to proprietary commercial platforms. So academic community should be now actively involved in coordinating and defining standards that ensure support for *sustainable development* of educational tools and keep open access and open content on high level of research agenda. Like in our suggested framework, new systems should inherently have flexible functionality supporting various kinds of educational needs and context, letting learner explore and express her creativity and personal identity.

There is a need to develop easily *tailorable user interfaces*, plug-ins and input devices so that the learners themselves can adjust and select most motivating ways to process knowledge in various forms to be incorporated to learning activities and addressing their background. Adaptive visualization and exploration of knowledge structures should exploit pioneering technology for personalization, for example promising generic input solutions addressing eye/gesture tracking, touch response, EEG bio-feedback, geo-positioning, inertia sensing and image recognition aspects. New tools should promote easy ways for the learners to share and collaboratively cumulatively *contribute to knowledge building process* in learning communities with captivating and inspiring experiences.

When learners intuitively invent, form and adopt new *educational practices* about how to link, agglomerate and traverse pieces of knowledge in their minds there needs to be ways to conveniently document and define these processes for future use and refinement. Like in our framework, new systems should offer recommendations for exploration in educational content on *various levels of abstraction* with such representation schemes that flexibly support chaining and looping in branching conceptual networks and capturing these exploration patterns into *expressive reusable templates*. Rich collection of automatically generated and updated templates should be instantly available for typical learning settings but they could be also modified and refined iteratively to address individual personal preference or collaboratively edited and ranked to form mutually agreed standards.

In publication [P8] we proposed a new educational framework relying on *cumulative conceptual networks* based on *hyperlink network of the Wikipedia* connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the *distribution of enabled hyperlinks*

connecting concepts belonging to current vocabulary. Adoption of knowledge can be gained by exploring hyperlink network and *the shortest paths* between concepts of vocabulary (especially concepts having highest rankings and strongly rising rankings). Publication [P8] also estimates properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to *six language ability levels*.

We think that already at the moment the Wikipedia basically contains so much useful knowledge that it could possibly cover a majority of all those situations dealing with a need of *factual knowledge* that a student can encounter during all his school years. However, this useful knowledge is not possibly organized and presented currently in *the most optimal form* to support independent cumulative adoption of knowledge that addresses the student's previous knowledge and personal needs as well as to help identifying the most essential content for current learning topic and to encourage inductive and deductive reasoning with sufficiently spaced and repeated exposure and retention.

Therefore we think that there is a great *potential for education* in the knowledge contained already now in the Wikipedia but to enable better learning opportunities relying on the Wikipedia the research community should invest on more analysis about the properties of the Wikipedia and to develop computational methods that let to transform its knowledge to various forms of representation to address personalized educational needs of a student.

We hope that the proposed framework can open new possibilities for developing innovative methods of computer-assisted learning relying on knowledge structures managed with *small-world networks* (and possibly a *scale-free version of small-world network* being the most preferable), which is a compact efficient form that inherently emerges with many natural process including formation of the hyperlink structure of the Wikipedia. We suggest that personalization of learning activities can benefit from exploring collaboratively built and gradually updated free knowledge resources of the Wikipedia online encyclopedia that inherently offers diverse collection of hyperlinks defining conceptual relationships usable for varied pedagogic purposes. We think that the principle of *cumulatively expanding hyperlink networks* covering more and more linkage between concepts of gradually growing vocabulary can enable an efficient and intuitive way to explore and adopt new knowledge meaningfully as well as to develop new kind of educational games that can be extended to manage diverse content besides text like images, videos, and tasks with augmented reality and tracking kinetic activities.

We think that personalized learning experience is affected by many factors and it is often difficult to control them systematically and in many cases it is not even necessary. We think that the information processing in *human neural system* has an inherent challenge that we are constantly exposed to an arriving information flow that is so high that our own ability to react, to make synthesis and generate new innovative information remains relatively limited in comparison. Therefore we think that it is important to create new educational methods to assist every learner in *filtering most meaningful information* for personal development, making synthesis and generating new

information resources that can be shared for collective benefit. On the other hand we think that to manage in conceptualization, learning and adoption of new knowledge human neural system requires some kind of continuity, repetition and looping, and also these aspects should be addressed when developing new educational methods.

We also think that *guided learning activities* should support voluntary efforts and offer surprising inspiring experiences. To provide for large populations equal yet personalized opportunity to learn essential entities of knowledge and skills needed in current society we think that it is useful to develop supporting methods that have a systematic underlying *motivation and structure*. These support methods should especially provide students with learning skills that include ability to collect and critically synthesize information from various sources as well foster creativity and innovation.

We think that conceptual networks based on *scale-free small-world network* structure can be beneficial for presenting *educational knowledge* offering efficient and compact form to build, manage and explore information. We think that tailored sequential processes of exposure and retention of pieces of knowledge following theory of *spaced learning* can fruitfully support cumulative adoption of knowledge. We think that since educational needs for each learner are unique, different alternative approaches and perspectives to learning topic should be encouraged and this can be supported with *modular and adaptive properties* of the structure of learning material. We think that to enable cost-efficient generation of educational experiences in learning sessions in a form that suits inherent cognitive and psychological characteristics of memory and human mind good opportunities are offered by *learner-driven* but at the same time sufficiently guided exploration in conceptual networks. Since learning new knowledge about current learning topic can be typically seen to consist of modular conceptual components and they typically have varied levels of significance and familiarity we think that a natural and intuitive learning process can be implemented by guided cumulative expanding exploration in a conceptual network of vocabulary concerning current learning topic and which is linked to previous vocabulary of learner.

We think that for any kind of knowledge entities *computational methods* can enable building and maintaining networks that can be used to manage educational material and to explore connectivities of *knowledge entities* to adopt cumulatively vocabulary and conceptual relationships. We think that it is useful to offer to student various ways to customize learning experience in conceptual networks by letting to adjust the connectivity between relationships so that for example typically dominant highest-ranking relationships are temporarily hidden so that weaker but still important relationships instead become highlighted. We think that learners should have a possibility to explore knowledge resources with *diverse perspectives* addressing their personal needs and to actively express their creativity in many ways including adoption of new knowledge, building knowledge representations about their conceptualization and cumulatively modifying them in collaborative process and also through activities that define new types of learning processes and games that can be actively shared and further iteratively refined in learning community and in surrounding society.

PART VI. Additional resources

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Appendix A

This doctoral dissertation is based on following eight publications P1-P8 which have been published in peer-reviewed conference proceedings between years 2009-2013, each supplied here with a short description.

P1: Lahti, L. (2009a). Assistive tool for collaborative learning of conceptual structures. Proc. 13th Human Computer Interaction International 2009, Part III (Universal Access in Human-Computer Interaction – Applications and Services), 19-24 July 2009, San Diego, CA, USA (ed. Stephanidis, C.). LNCS 5616, Springer, 53-62. Print ISBN 978-3-642-02712-3 and Online ISBN 978-3-642-02713-0. http://link.springer.com/chapter/10.1007/978-3-642-02713-0_6

In this publication we propose a new collaborative scheme to assist learning conceptual structures in a collaborative Web environment. We have implemented a prototype enabling collaborative ideation to build shared concept maps representing conceptualization of learners. We suggest supporting different collaborator roles to address personal needs of each learner participating in collaboration. We propose combining role-driven text-based parallel individual discussion chains that are illustrated cumulatively in a collaboratively agreed concept map.

Discussed in Chapter 4.

P2: Lahti, L. (2009b). Guided generation of pedagogical concept maps from the Wikipedia. Proc. World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education (E-Learn 2009). 26-30 October 2009, Vancouver, B.C., Canada (eds. Bastiaens, T. et al.). Association for the Advancement of Computing in Education (AACE), Chesapeake, Virginia, USA, 1741-1750. ISBN 1-880094-76-2. <http://www.editlib.org/p/32712>

In this publication we propose a new method for guided generation of concept maps from open access online knowledge from the Wikipedia online encyclopedia. Our method extracts semantic relations from sentences surrounding hyperlinks in the Wikipedia's articles and lets a learner to create customized learning objects in real-time based on collaborative recommendations considering her earlier knowledge.

Discussed in Chapter 5.

P3: Lahti, L. (2010a). Personalized learning paths based on Wikipedia article statistics. Proc. 2nd International Conference on Computer Supported Education (CSEDU 2010), 7–10 April 2010, Valencia, Spain (eds. Cordeiro, J. et al.), Vol. 1, 110-120. SciTePress, Institute for Systems and Technologies of Information, Control and Communication (INSTICC). ISBN 978-989-674-023-8. <http://dx.doi.org/10.5220/0002800901100120>

In this publication we propose a new semi-automated method for generating personalized learning paths from the Wikipedia online encyclopedia by following inter-article hyperlink chains based on various rankings that are retrieved from the statistics of the articles. Alternative perspectives for learning topics are achieved based on hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate, editing rate, or user-defined weighted mixture of them all enabling the learner to build independently concept maps following her needs and consideration.

Discussed in Chapter 6.

P4: Lahti, L. (2010b). Educational tool based on topology and evolution of hyperlinks in the Wikipedia. Proc. 10th IEEE International Conference on Advanced Learning Technologies (ICALT 2010), 5–7 July 2010, Sousse, Tunisia (eds. Jemni, M. et al.), 233-235. ISBN 978-0-7695-4055-9 and ISBN 978-1-4244-7144-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5571281

In this publication we propose a new method to support educational exploration in the hyperlink network of the Wikipedia online encyclopedia. This extends the method introduced in publication P3 in respect to three important new features: the learner can simultaneously operate with parallel

ranking lists of hyperlinks, the concept map construction emphasizes building diversely branching structures, and different consecutive temporal versions of Wikipedia articles can be browsed. Discussed in Chapter 7.

P5: Lahti, L. (2011a). ConceptMapWiki – a collaborative framework for agglomerating pedagogical knowledge. Proc. 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), 6–8 July 2010, Athens, Georgia, USA (eds. Aedo, I. et al.), 163-165. Online ISBN 978-0-7695-4346-8 and Print ISBN 978-1-61284-209-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5992312

In this publication we propose a new educational framework, ConceptMapWiki, that is a wiki representing pedagogical knowledge with a collection of concept maps which is collaboratively created, edited and browsed. The learners and educators provide complementing contribution to evolving shared knowledge structures stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria. Pedagogically motivated learning paths can be collaboratively defined and evaluated, and educational games can be incorporated based on browsing and editing concept maps. Discussed in Chapter 8.

P6: Lahti, L. (2011b). Educational concept mapping method based on high-frequency words and Wikipedia linkage. Proc. 4th International Conference on Internet Technologies and Applications (ITA11), 6–9 September 2011, Wrexham, North Wales, UK (eds. Grout, V. et al.). Glyndwr University, Wrexham, Wales, UK. ISBN 978-0-946881-68-0. <http://www.ita11.org/papers.html>; <http://www.ita11.org/detailedProgramme.html>; <http://www.lulu.com/shop/vic-grout-and-stuart-cunningham-and-denise-oram-and-rich-picking/proceedings-of-the-fourth-international-conference-on-internet-technologies-and-applications-ita-11/ebook/product-17431522.html>

In this publication we propose a new computational method to support the learner's knowledge adoption based on concept mapping relying on three perspectives: learner's knowledge, learning context and learning objective. Each perspective is represented by a learning concept network that is generated based on a set of high-frequency words from a representative text sample that are connected based on the shortest hyperlink chains between corresponding Wikipedia articles. The learner explores ranking-based routings connecting learning concept networks by expanding a concept map.

Discussed in Chapter 9.

P7: Lahti, L. (2012). Educational framework for adoption of vocabulary based on Wikipedia linkage and spaced learning. Proc. Global Learn 2012: Global Conference on Learning and Technology, online conference on 6 November 2012 (eds. Bastiaens, T., & Marks, G.), pp. 8-13. Association for the Advancement of Computing in Education (AACE). ISBN 1-880094-99-1. <http://www.editlib.org/p/42033/>

In this publication we propose a new educational framework relying on pedagogic conceptual network generated by linking the most essential concepts of learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary. To adopt vocabulary the learner traverses links of pedagogic conceptual network along learning path generated by method in sequential process having tailored variation and repetition computed based on theory of spaced learning. The learning path is shown to learner as sequence of compact relation statements extracted from sentences surrounding hyperlinks in Wikipedia articles, supplied with set of visualizations based on main verb identified in them.

Discussed in Chapter 11, starting from Subchapter 11.1.

P8: Lahti, L. (2013). Educational framework based on cumulative vocabularies, conceptual networks and Wikipedia linkage. Proc. London International Conference on Education (LICE 2013). 4-6 November 2013, London, UK.

In this publication we propose a new educational framework relying on cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the distribution of enabled hyperlinks connecting concepts belonging to current vocabulary. Adoption of knowledge can be gained by exploring hyperlink network and the shortest paths between concepts of vocabulary (especially concepts having highest rankings and strongly rising rankings). Publication also estimates properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to six language ability levels. Discussed in Chapter 11, starting from Subchapter 11.2.

Appendix B

Main themes of our research can be explained by formulating a list of questions, with an aim to find suitable balance between broad coverage and specific attention to details.

1. How learners could be fruitfully combined into *collaborative educational groups* complementing each other's strengths and contributions with a system supporting computer-assisted learning? How the collaborator roles can be easily identified, distributed and supported with the automated system? How *collaborative learning efforts can be cumulated into a shared visualization* representing agreed conceptualization? How negotiation and ideation (brainstorming) between participating learners representing complementing collaborator roles can be organized in a systematic well documented and referenced way?
2. How knowledge content and its structures collaboratively created and edited in open access knowledge resources could be exploited in computer-assisted learning? Especially *how to exploit the extensive resources of the Wikipedia online encyclopedia* being currently the largest encyclopedia available? How the learner could be provided with fruitful *personalized support by getting recommendations how to pedagogically explore knowledge resources*? How the learner could cumulatively build own visual representations of the knowledge explored so far? Especially how to visualize explorations with concept maps due to their compactness and expressiveness?
3. How the learner's *exploration in knowledge resource of the Wikipedia* could be fruitfully *personalized and tailored based on simple statistical features* already present in knowledge content and its structures? How recommendations could be generated based on a compact set of diverse features reflecting important characteristics of learning process? How this exploration can be represented and visualized fluently in a compact and intuitive way using concept maps?
4. How the learner could build concept maps representing *diverse exploration paths in the knowledge resources of the Wikipedia* exploiting possibilities of simultaneously operating with *parallel ranking lists of hyperlinks*, emphasizing in the concept map construction building diversely branching structures, and browsing different *consecutive temporal versions* of Wikipedia articles?
5. How a new educational framework could be defined to support the community of learners to generate together a *wiki representing pedagogical knowledge with a collection of concept maps* which is collaboratively created, edited and browsed? How the learners and educators could provide complementing contribution to evolving shared knowledge structures stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria? How *pedagogically motivated learning paths can be collaboratively defined and evaluated*, and how educational games can be incorporated based on browsing and editing a concept map collection?
6. How the process of adoption of new knowledge by the learner could be best supported in connecting the learner's prior knowledge fruitfully to new knowledge? How the *knowledge resource of the Wikipedia* and its knowledge structures could be exploited *to provide efficient linking between prior and new knowledge*? How the *learning context* and the *collective cumulative knowledge of the learner community* could provide diverse supporting guidance for adoption of new knowledge? How this learning process could be intuitively visualized?
7. How the learner's *exploration in hyperlink network of the Wikipedia as a sequential process* could be guided pedagogically rewardingly to adopt vocabulary and new knowledge? How this sequential process could be best *supported with tailored variation and repetition* addressing functional principles of living neural system and memory? What are the most *optimal spacing intervals for exposure and retention of pieces of knowledge to be learned*? What kind of parameters are useful to be taken into account when trying to optimize the adoption of knowledge and how these parameters could be well measured and adjusted?

8. How educational material could be presented to the student with a personalized and cumulative form that well supports *adoption of vocabulary and new knowledge*? How the connectivity of conceptual network can be flexibly alternated along learning to offer gradually expanding coverage of vocabulary? What kind of empirical estimates can be made about properties of cumulative vocabularies and conceptual networks when a *learner goes through typical language ability levels*? What kind of *conceptual linkage and exploration patterns* can be generated *based on the Wikipedia hyperlink network* to represent conceptualization of an average child or adult?

We have tried to formulate these questions so that in the given order they form a continuity and open gradually enriching perspectives to our research of developing computer-assisted learning. These questions one by one become under focus in publications [P1]-[P8], thus publication [P1] trying to address question 1, publication [P2] question 2, and so on.

Appendix C

Need for open access and open source solutions

We think that it is important to guarantee a reasonable income for all parties involved in making creative work but at the same time it is also important to support development of very low-cost or free online services that can be used by anyone. Naturally, innovation is needed to find new ways to cover costs that originate from providing free services. Operation of some of the existing free services seem to rely on persons devoted to do voluntary work and some others rely on advertisements shown parallel to actual meaningful knowledge content.

It has been speculated and criticized that some of the free web services have such a hidden business model that they actively gather *sensitive user data* while the user uses the services even if not clearly indicating this to the user and some services questionably try to claim that they will get full ownership of all data submitted by the user to the system. There is a well motivated fear that privacy and rights of the users of these web services can be severely compromised and there is a need to develop ways to block unwanted tracking done by web services and application of such terms of use that excessively limit the user's freedom.

We think that it is important to have non-commercial preferably voluntary based actors in the development of software engineering and also academic researchers trying to produce *open public systems* whose performance and claims concerning using them can be objectively verified. In the availability and use of information resources of the World Wide Web it has become very important how the global information resources can be accessed and just a few search engine providers have become very dominant by taking a position as a *gatekeeper* for knowledge retrievable with given key words. It can be considered a great problem that just one commercial company, Google, is seriously dominating global web surfing and having control of large amount of other user data through Google search engine, Android operating system, Google Chrome web browser, Gmail email service, Youtube online video viewer, Google maps location service and Google Ads advertisement service having possibly tracking components placed on a large variety of ordinary web pages.

Providers of currently dominating commercial search engines while functioning as gatekeepers have a lot of control on how global community can access and interpret available knowledge about a desired topic and it is very difficult to evaluate the *objectiveness* of the principles that are used to generate search results. Typically the algorithms used to generate search results are not openly revealed to public know and this has been explained to be motivated by trade secrets and preventing fraud by exploiting misleadingly the principles of algorithms. Anyway, we think that people should have a right to know in detail the principles how information and knowledge they retrieve from web resources are filtered and ranked. Thus we think that it is important to develop *non-commercial community driven services* that can be used for filtering and ranking knowledge and also that the methods used for filtering and ranking can be publicly and openly evaluated, criticized, verified and developed further.

In the community driven and open access movement to support learning on a large scale in the Web we see two important distinct approaches to offer services. First approach is a *search engine type of services* that offers guidance to access links to a variety of ordinary web pages that are external to the actual system and a community collectively evaluates them and supplies a descriptive tagging to each of them. Then an index is created about these web pages supplied with tags to help finding appropriate web pages best matching the learner's needs given typically with search key words.

Second approach is a *knowledge base type of services* in which knowledge content is collaboratively cumulated created, evaluated and edited by members of the community themselves and stored in full detail to a self-containing system having a specific organization. To help the learner to find needed information the organization of knowledge is purposfully built with a hierarchy and link structure representing semantic relationships of knowledge and access to edit histories.

Appendix D

Potential of evolving computer technology

To understand better the underlying motivations and potential of developing new innovative computer-based systems we think that it is important to see the progressive rapid technological evolution that has enabled to achieve new approaches for processing and maturing knowledge. From engineering viewpoint innovations starting from 19th century managing to both model and apply *electro-magnetic phenomena* has enabled a great deal of development of for example telephone networks, radio and television technology as well as microprocessors and personal computers (PCs). A major reform for both computer technology and human interaction in general has been the development and relatively inexpensive adoption of *mobile phones* and the publicly open *Internet* since 1990's. From cable-based Internet connection serving simple static webpage and email in stationary workstations we have rapidly proceeded to possibility to use complex dynamic cloud-based services that can be used with wireless Wide Local Area Networks (WLANs) and third generation (3G) mobile telecommunication networks with mobile laptops, smartphones, netbooks and tablets almost everywhere in popular urban and rural areas.

Even if increase in computational efficiency finds always new needs, it is meaningful to recognize that almost any typical *low-priced mobile computerized device* now available on consumer market typically greatly surpasses most state-of-the-art *super computers* few decades ago in respect to for example computational power, communicational bandwidth, displays (high definition, 3d etc.) and input devices (touch screens, sensors etc.). We think that both in research and ordinary living people should remind themselves actively to appreciate and to be aware of the exciting new possible application domains that have gradually emerged with amazingly high pace with the computational and communicational advances. We are facing new great opportunities of technological and intellectual advancement for humanity that should be exploited vigorously.

Computer-assisted learning has been a sector of *academic research* and *practical educational work* already several decades. Bringing unnecessary confusion, terminology used in this context has been varied and changing along the years even if referring to same old methods and theories in a bit new form. Typically different trends and *unrealistic hype* can be seen especially in commercial field trying to convince potential customers to invest in to new applications of technology. Frequently new promising and “revolutionary” educational practices are introduced with great publicity but most of these initiatives cannot gain significant momentum of followers in the long run. However, it is often laborious to develop methods that can be shown to offer a real substantial educational advantage for the learning process. Therefore it might appear to many observers that progress in the research of educational technology is irritatingly slow and limited. On the other hand, *open access* movement and *open source* movement have challenged the traditional commercial business oriented software industry by requesting use of less restricted and less formal ways of sharing information and tools.

Along the rise of Internet and active introduction and adoption of web based services, there has been increasing movement to implement new tools as online applications instead of standalone workstation based applications. Furthermore, many new web services are even provided free of charge to consumers although at the same time often forcing the users to allow their activities to be tracked with a questionably intimidating scale of detail. For reasons of efficiency, economy and scalability, using *distributed and cloud based resources* are increasing trends. This has lead to controversial situations where the users themselves are not anymore actually holding the hardware storing their own personal data and *users are not able to fully control* how their own data is

governed for example on foreign data servers, especially due to incomplete and conflicting international legislation. In addition, new distributed applications are increasingly launched and provided without clear versioning in a somewhat *permanent beta testing* phase without guarantee of continuity. Also there has emerged yet partly unsolved problems concerning management and protection of *intellectual property rights* in respect to software and information and media content shared flexibly through distributed resources. There is a need to develop methods that enable individuals easily and reliably manage their own personal data with guaranteed privacy but at the same time enabling individuals to fruitfully contribute to collaborative processes of building and sharing knowledge resources through Internet.

Appendix E

This listing shows two alternatively computed high-frequency word lists of 110 highest-ranking common nouns of British National Corpus ((Kilgarriff 1997); (Leech et al. 2001)), relying on about 100 million word corpus, and similarly 110 highest-ranking common nouns of Corpus of Contemporary American English ((Davies & Gardner 2010); (Word frequency data from COCA 2013)), relying on about 400 million word corpus, that reveal together some variation in rankings of everyday vocabulary. We could not fully understand why in online frequency lists of Corpus of Contemporary American English some of the frequencies did not seem to systematically descend along the provided rank position but anyway we decided to use these lists for our analysis.

Rank position	Lemmatized words in British National Corpus (Kilgarriff 1997)		Lemmatized words in British National Corpus (Leech et al. 2001)		Lemmatized words in Corpus of Contemporary American English 2013 ((Davies & Gardner 2010); (Word frequency data from COCA 2013))	
	noun concept (rank among all words (including nouns and other part-of-speech))	frequency	noun concept (rank among all words (including nouns and other part-of-speech))	frequency per million words	noun concept (rank among all words (including nouns and other part-of-speech))	frequency
1	time (53)	183427	time (53)	1833	time (52)	764657
2	year (60)	163930	year (60)	1639	year (54)	769254
3	people (80)	125430	people (79)	1256	people (62)	691468
4	way (89)	112636	way (90)	1108	way (84)	470401
5	man (101)	97985	man (95)	1003	day (90)	432773
6	day (104)	92699	day (100)	940	man (94)	409760
7	thing (115)	77612	thing (111)	776	thing (97)	400724
8	child (121)	71008	child (121)	710	woman (111)	341422
9	government (133)	66894	mr (131)	673	life (114)	333085
10	part (135)	65773	government (132)	670	child (115)	333849
11	life (137)	64423	work (134)	653	world (123)	303506
12	case (140)	63577	life (138)	645	school (125)	304183
13	woman (141)	63087	woman (140)	631	state (137)	272193
14	work (146)	62248	system (146)	619	family (147)	243267
15	system (149)	61912	case (149)	613	student (157)	255047
16	group (155)	60689	part (150)	612	group (163)	229435
17	number (156)	60607	group (152)	607	country (166)	223138
18	world (161)	59094	number (153)	606	problem (171)	217728
19	area (162)	58449	world (156)	600	hand (174)	225247
20	course (164)	57776	house (158)	598	part (178)	207861
21	company (165)	57754	area (159)	585	place (181)	202427
22	problem (168)	56483	company (162)	579	case (186)	200773
23	service (173)	54468	problem (166)	565	week (188)	199268

24	hand (176)	53265	service (173)	549	company (189)	2033 45
25	party (177)	52979	place (175)	534	system (191)	2001 75
26	school (181)	52227	hand (176)	532	program (194)	1959 85
27	place (184)	51537	party (178)	529	question (197)	1920 70
28	point (190)	49187	school (179)	529	work (199)	1875 33
29	house (191)	49022	country (187)	486	government (201)	1913 14
30	country (193)	48177	point (189)	484	number (204)	1860 05
31	week (196)	47512	week (194)	476	night (209)	1845 11
32	member (199)	47141	member (195)	471	mr (211)	1885 55
33	end (206)	45160	end (201)	458	point (212)	1774 81
34	word (213)	43750	state (210)	440	home (225)	1705 27
35	example (216)	43402	word (212)	438	water (227)	1676 66
36	family (218)	42773	family (217)	428	room (228)	1724 72
37	fact (220)	42241	fact (218)	426	mother (230)	1694 07
38	state (224)	41351	head (227)	402	area (231)	1658 12
39	percent (225)	41205	month (231)	398	money (233)	1647 94
40	home (235)	39850	side (232)	398	story (234)	1635 82
41	month (236)	39819	business (233)	394	fact (236)	1644 01
42	side (237)	39626	night (234)	393	month (237)	1626 85
43	night (238)	39315	eye (235)	392	lot (239)	1695 70
44	eye (240)	39192	home (239)	390	right (240)	1632 59
45	head (241)	39000	question (240)	390	study (241)	1740 69
46	information (242)	38656	information (242)	387	book (242)	1540 13
47	question (243)	38608	power (245)	385	eye (243)	1691 50
48	business (244)	38204	change (246) (per_cent shares same position and frequency as change according to (http://ucrel.lancs.ac.uk/bncfreq/lists/5_1_all_rank_noun.txt)	384	job (244)	1547 43
49	power (246)	37963	interest (250)	376	word (245)	1528 91
50	money (247)	37892	development (253)	375	business (247)	1544 68
51	change (248)	37884	money (254)	375	issue (248)	1564 17
52	interest (250)	37744	book (255)	374	side (249)	1525 59
53	order (251)	37736	water (256)	372	kind (250)	1550 32
54	book (252)	37675	other (259)	367	head (252)	1601 31
55	development (254)	37386	form (260)	365	house (258)	1492 51
56	room (259)	36360	room (261)	364	service (264)	1461 22
57	water (261)	35767	level (262)	360	friend (266)	1426 97
58	form (262)	35758	car (267)	353	father (268)	1450

						51
59	car (263)	35295	council (271)	348	power (272)	1413 57
60	other (264)	35164	policy (272)	348	hour (273)	1389 55
61	level (268)	34885	market (274)	346	game (274)	1463 11
62	policy (271)	34775	court (277)	344	line (277)	1359 86
63	council (274)	34496	effect (285)	336	end (279)	1341 04
64	line (278)	33888	result (287)	334	member (286)	1347 31
65	need (280)	33660	idea (292)	328	law (288)	1337 06
66	effect (281)	33423	use (293)	328	car (290)	1335 71
67	use (283)	32998	study (294)	327	city (291)	1326 84
68	idea (286)	32798	job (296) name (296)	326 326	community (297)	1330 57
69	study (287)	32786			name (299)	1271 39
70	lot (288)	32733	body (299)	325	president (304)	1342 03
71	job (290)	32484	report (300)	325	team (308)	1314 89
72	name (292)	32309	line (301)	323	minute (309)	1266 60
73	result (293)	32259	law (302)	318	idea (312)	1221 40
74	body (294)	32231	face (305)	315	kid (313)	1264 28
75	friend (296)	31927	friend (306)	315	body (314)	1251 65
76	right (297)	31873	authority (308)	313	information (315)	1273 31
77	authority (303)	31231	road (309)	313	back (323)	1250 06
78	view (306)	31102	minister (319)	305	parent (328)	1196 10
79	report (311)	30857	rate (323)	303	face (331)	1272 91
80	bit (315)	30675	door (324) hour (324)	302 302	others (337)	1157 71
81	face (316)	30624			level (339)	1217 04
82	market (318)	30596	office (329)	300	office (342)	1147 91
83	hour (324)	30218	right (330)	299	door (344)	1249 93
84	rate (325)	30179	war (331)	297	health (345)	1177 62
85	law (326)	30169	mother (332)	295	person (346)	1136 50
86	door (327)	30166	person (335)	290	art (347)	1178 51
87	court (328)	29976	reason (337)	289	war (350)	1178 04
88	office (329)	29943	view (338)	289	history (351)	1149 04
89	war (331)	29722	term (343)	288	party (352)	1129 62
90	reason (333)	29194	period (352)	283	result (355)	1162 77
91	minister (335)	29141	centre (353)	282	change (357)	1124 26
92	subject (336)	29091	figure (354) society (354)	282 282	morning (358)	1140 02
93	person (337)	28981			reason (360)	1068 63
94	term (338)	28896	police (356)	278	research (363)	1148 02
95	sort (342)	28760	city (359)	275	girl (364)	1104 09
96	period (348)	28300	need (362)	273	guy (365)	1104 09

97	society (352)	28150	community (364) million (364)	272 272	food (367)	1077 28
98	process (353)	28035			moment (369)	1097 20
99	mother (354)	27784	kind (367)	271	air (371)	1059 32
100	voice (357)	27665	price (368)	271	teacher (372)	1161 00
101	police (360)	27508	control (369)	270	force (373)	1080 05
102	kind (361)	27485	action (370) cost (370) issue (370) process (370)	269 269 269 269	education (377)	1137 31
103	price (369)	27166			foot (381)	1072 85
104	action (371)	26894			boy (383)	1074 47
105	issue (372)	26889			age (387)	1034 02
106	position (375)	26625	position (376)	268	policy (389)	1076 01
107	cost (377)	26556	course (377)	267	process (392)	1073 41
108	matter (379)	26304	minute (378)	266	music (393)	1026 57
109	community (380)	26289	education (383)	260	market (403)	1004 35
110	figure (382)	26191	type (385)	259	sense (408)	9589 6

Appendix F

This listing shows 102 core concepts of concept maps drawn by students and the closest matching entry of Wikipedia article corresponding to the concept. Although according to this listing concept “sister” mentioned in concept maps corresponds to Wikipedia article Sibling it needs to be noted that also concept “brother” mentioned in concept maps (but not belonging to these 102 highest-ranking concepts) corresponds to the same Wikipedia article Sibling. In the Wikipedia both entry Sister and entry Brother are redirected to shared article Sibling and thus in the Wikipedia word “sibling” can be considered to represent both words “brother” and “sister”.

When analyzing conceptual relationships between 102 core concepts we made a decision to form a collection of altogether 145 conceptual relationships, called **core relationships**, aiming to represent knowledge structures of the students between 102 core concepts extended with concept “brother”. When comparing drawn concept maps to hyperlink structure of the Wikipedia, for example in Appendix N, concepts of concept maps can be transformed to a spelling that matches corresponding Wikipedia articles and thus concept “brother” can be transformed to a spelling that is Sibling.

<i>Concept in concept maps drawn by students</i>	<i>Original Finnish spelling of concept in concept maps drawn by students</i>	<i>The closest matching entry of Wikipedia article corresponding to the concept</i>
air	ilma	Atmosphere_of_Earth
animal	eläin	Animal
baby	vauva	Infant
bed	sänky	Bed
biology	biologia	Biology
birth	syntymä	Birth
book	kirja	Book
bread	leipä	Bread
car	auto	Automobile
cat	kissa	Cat
chair	tuoli	Chair
child	lapsi	Child
childhood	lapsuus	Childhood
city	kaupunki	City
clock	kello	Clock
cloth	vaate (in exploration task replaced with: vaatetus)	Clothing
computer	tietokone	Computer
death	kuolema	Death
disease	sairaus	Disease
dog	koira	Dog
dream_(sleeping)	uni	Dream
eating	syöminen	Eating
education	koulutus	Education
elderness	vanhuus	Old_age
emotion	tunne	Emotion
environment	ympäristö	Environment
evolution	evoluutio	Evolution
exam	koe	Test_(assessment)
experience	kokemus	Experience
family	perhe	Family
father	isä	Father
flower	kukka	Flower
food	ruoka	Food
forest	metsä	Forest
freetime	vapaa-aika	Leisure
friend	ystävä (in exploration task replaced with: ystävyys)	Friendship
fun	hupi	Fun
future	tulevaisuus	Future
goal_(to_achieve)	tavoite	Goal
god	jumala	God
goodness	hyvyys	Goodness
ground	maa	Ground

growing	kasvaminen	Growing
happiness	onnellisuus	Happiness
hate	viha	Hatred
health	terveys	Health
heart	sydän	Heart
hobby	harrastus	Hobby
holiday	loma	Holiday
home	koti	Home
hospital	sairaala	Hospital
house	talo	House
human	ihminen	Human
joy	ilo	Joy
learning	oppiminen	Learning
light	valo	Light
living	eläminen	Living
love	rakkaus	Love
marriage	avioliitto	Marriage
money	raha	Money
mother	äiti	Mother
music	musiikki	Music
nature	luonto	Nature
nutriment	ravinto	Diet_(nutrition)
organism	eliö	Organism
oxygen	happi	Oxygen
paper	paperi	Paper
parent	vanhempi	Parent
party	juhla	Party
peace	rauha	Peace
pen	kynä	Pen
people	ihminen_(ryhmä)	People
pet	lemmikki (in exploration task replaced with: lemmikkieläin)	Pet
philosophy	filosofia	Philosophy
phone	puhelin	Telephone
physical_training	liikunta	Physical_fitness
plant	kasvi	Plant
pleasure	nautinto	Pleasure
purpose	tarkoitus	Purpose
rain	sade	Rain
religion	uskonto	Religion
sadness	surullisuus	Sadness
school	koulu	School
sea	meri	Sea
shoe	kenkä	Shoe
sister	sisko (in exploration task replaced with: sisarus)	Sibling
sorrow	suru	Sorrow
sport	urheilu	Sport
study	opiskelu	Study
succeeding	onnistuminen	Management
summer	kesä	Summer
sun	aurinko	Sun
teacher	opettaja	Teacher
television	televisio	Television
time	aika	Time
travel	matka (in exploratio task replaced with: matkustaminen)	Travel
tree	puu	Tree
war	sota	War
water	vesi	Water
work	työ	Work
world	maailma	World
young_(person)	nuori (in exploration task replaced with: nuoruus)	Adolescence

Appendix G

Number of unique start concepts and unique end concepts as well as unique start/end concepts for hyperlinks between Wikipedia articles (as of in the beginning of March 2008), especially among 102 core concepts and considering hyperlinks departing from full text section and intro text section. In column 6 and column 9 that show “number of unique start/end concepts” each concept is counted only once even if occurring as both start and end concept.

Observed concept	Number of unique end concepts for hyperlinks departing from full text section of observed concept	Number of unique end concepts for hyperlinks departing from only intro text section of observed concept	Number of unique end concepts for hyperlinks departing from full text section of observed concept to any of 102 core concepts	Number of unique start concepts for hyperlinks arriving from full text section of any of 102 core concepts to observed concept	Number of unique start/end concepts for such hyperlinks that either arrive from full text section of observed concept or depart from full text section of observed concept to any of 102 core concepts	Number of unique end concepts for hyperlinks departing from only intro text section of observed concept to any of 102 core concepts	Number of unique start concepts for hyperlinks arriving from only intro text section of any of 102 core concepts to observed concept	Number of unique start/end concepts for such hyperlinks that either arrive from only intro text section of observed concept or depart from only intro text section of observed concept to any of 102 core concepts
Adolescence	190	6	7	8	10	1	0	1
Animal	245	13	10	10	15	2	3	5
Atmosphere_of_Earth	194	20	9	4	9	2	0	2
Automobile	709	5	1	3	3	0	0	0
Bed	161	15	3	1	3	0	0	0
Biology	305	19	9	11	13	1	3	3
Birth	64	9	4	1	5	2	1	3
Book	315	17	2	2	3	1	0	1
Bread	451	30	4	1	4	2	0	2
Cat	457	25	3	2	3	1	0	1
Chair	78	11	0	0	0	0	0	0
Child	102	3	9	7	10	1	2	3
Childhood	66	5	4	6	6	2	1	3
City	425	10	3	1	4	0	0	0
Clock	391	9	3	2	3	1	0	1
Clothing	212	36	4	3	6	1	0	1
Computer	459	18	2	2	4	0	0	0
Death	323	14	9	7	14	2	2	3
Diet_(nutrition)	59	11	4	5	7	4	0	4
Disease	184	18	1	5	5	1	2	2
Dog	452	17	3	2	3	1	1	1
Dream	186	4	2	1	2	0	0	0
Eating	53	16	5	3	7	5	2	6
Education	254	16	13	9	17	2	4	5
Emotion	210	5	8	7	10	2	2	4
Environment	19	no intro text section available	0	0	0	no intro text section available	0	0
Evolution	419	26	5	11	14	1	2	2
Experience	237	25	2	3	5	0	3	3
Family	152	6	6	12	12	1	5	5
Father	92	30	6	5	7	3	2	3
Flower	221	5	2	2	3	0	0	0
Food	343	18	12	5	14	1	1	1
Forest	146	12	4	2	4	1	0	1

Friendship	103	45	4	1	4	1	0	1
Fun	1	no intro text section available	0	0	0	no intro text section available	0	0
Future	151	no intro text section available	7	2	7	no intro text section available	0	0
Goal	42	5	1	2	2	0	1	1
God	252	27	4	7	9	1	0	1
Goodness	1	no intro text section available	0	0	0	no intro text section available	0	0
Ground	16	no intro text section available	1	0	1	no intro text section available	0	0
Growing	5	no intro text section available	0	0	0	no intro text section available	0	0
Happiness	69	3	2	8	8	2	2	4
Hatred	123	no intro text section available	5	5	6	no intro text section available	0	0
Health	153	2	5	7	8	1	2	3
Heart	145	11	0	3	3	0	0	0
Hobby	121	2	8	0	8	1	0	1
Holiday	80	4	0	0	0	0	0	0
Home	33	5	3	1	3	1	1	2
Hospital	192	8	2	2	4	0	0	0
House	197	8	4	3	6	2	0	2
Human	871	15	20	15	33	0	8	8
Infant	139	8	6	5	7	1	1	2
Joy	81	no intro text section available	1	2	2	no intro text section available	1	1
Learning	92	14	4	2	5	2	1	2
Leisure	106	11	8	6	11	4	1	5
Light	242	17	3	2	4	0	0	0
Living	17	no intro text section available	0	0	0	no intro text section available	0	0
Love	238	5	11	11	16	2	2	4
Management	242	9	0	0	0	0	0	0
Marriage	473	23	8	9	13	3	2	4
Money	232	12	2	1	3	0	0	0
Mother	168	26	8	5	9	3	3	4
Music	254	21	3	6	9	0	0	0
Nature	323	19	10	5	11	1	0	1
Old_age	87	11	6	5	7	1	0	1
Organism	229	31	4	10	11	1	6	7
Oxygen	498	51	9	11	16	1	3	4
Paper	186	10	2	4	4	0	3	3
Parent	68	6	6	4	6	4	4	6
Party	94	1	3	0	3	0	0	0
Peace	78	5	2	1	2	0	0	0
Pen	59	3	1	0	1	1	0	1
People	71	13	4	1	5	1	0	1
Pet	85	8	4	3	5	2	1	2
Philosophy	505	6	3	16	17	0	4	4
Physical_fitness	34	2	2	3	4	1	0	1
Plant	420	18	12	16	19	2	3	5
Pleasure	88	5	7	4	7	1	0	1
Purpose	38	4	4	2	5	1	0	1
Rain	97	8	3	4	6	1	0	1
Religion	479	20	5	13	15	1	5	6
Sadness	125	9	6	5	6	2	0	2
School	172	17	2	3	3	2	0	2
Sea	149	13	1	1	1	0	1	1
Shoe	425	8	1	0	1	0	0	0

Sibling	92	7	6	8	9	3	0	3
Sorrow	10	no intro text section available	1	1	1	no intro text section available	1	1
Sport	127	3	1	3	4	0	0	0
Study	9	no intro text section available	0	0	0	no intro text section available	0	0
Summer	48	2	1	0	1	0	0	0
Sun	452	51	2	7	8	1	0	1
Teacher	136	7	4	3	5	0	1	1
Telephone	120	6	0	1	1	0	0	0
Television	162	14	0	10	10	0	0	0
Test_(assessment)	100	19	4	0	4	1	0	1
Time	492	28	8	13	18	2	2	4
Travel	26	no intro text section available	0	1	1	no intro text section available	0	0
Tree	367	20	3	2	4	1	2	3
War	448	19	4	4	7	0	0	0
Water	523	32	10	9	15	2	2	4
Work	24	no intro text section available	0	1	1	no intro text section available	1	1
World	53	12	2	0	2	2	0	2
<i>Sum of hyperlinks unique to each observed concept</i>	20512 (14907 unique to collection of all observed concepts)	1243 (1055 unique to collection of all observed concepts)	422 (85 unique to collection of all observed concepts)	422 (88 unique to collection of all observed concepts)	652 (93 unique to collection of all observed concepts)	100 (43 unique to collection of all observed concepts)	100 (60 unique to collection of all observed concepts)	182 (70 unique to collection of all observed concepts)
<i>Average</i>	201.1 (\approx 20512/102)	14.0 (\approx 1243/89)	4.1 (\approx 422/102)	4.1 (\approx 422/102)	6.4 (\approx 652/102)	1.1 (\approx 100/89)	1.0 (\approx 100/102)	1.8 (\approx 182/102)
<i>Median value</i>	151.5	11	3.5	3	5	1	0	1

Appendix H

Comparison of number of unique start concepts and unique end concepts as well as unique start/end concepts for hyperlinks in the Wikipedia and relationships in concept maps drawn by students, especially among 102 core concepts. Values concerning the Wikipedia (in columns 2-4) are based on Appendix G considering hyperlinks departing from full text section of articles. In column 2 that shows “number of unique start/end concepts” each concept is counted only once even if occurring as both start concept and end concept. Respectively in column 5 each concept is counted only once even if occurring as both start concept and end concept and even if it is possibly mentioned by several students. In column 6 showing “number of start/end concepts (duplicates allowed)” each concept becomes counted twice if occurring both as start concept and end concept and in addition becomes counted as many times as it is mentioned by students.

Observed concept	In Wikipedia			In concept maps	
	Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique start/end concepts in relationships for observed concept mentioned by at least two students in concept maps among 102 core concepts	Number of start/end concepts (duplicates allowed) in relationships for observed concept mentioned by at least two students in concept maps among 102 core concepts
Human	33	20	15	9	30
Plant	19	12	16	2	10
Time	18	8	13	0	0
Education	17	13	9	3	10
Philosophy	17	3	16	0	0
Love	16	11	11	12	46
Oxygen	16	9	11	1	2
Animal	15	10	10	8	27
Religion	15	5	13	1	3
Water	15	10	9	8	26
Death	14	9	7	9	42
Evolution	14	5	11	0	0
Food	14	12	5	5	17
Biology	13	9	11	1	3
Marriage	13	8	9	0	0
Family	12	6	12	24	107
Leisure	11	8	6	4	9
Nature	11	10	5	13	44
Organism	11	4	10	2	4
Adolescence	10	7	8	1	2
Child	10	9	7	4	13
Emotion	10	8	7	1	2
Television	10	0	10	3	8
Atmosphere_of_Earth	9	9	4	2	6
God	9	4	7	2	4
Mother	9	8	5	4	16
Music	9	3	6	1	2
Sibling	9	6	8	2 (brother)	4 (brother)
Happiness	8	2	8	3	11
Health	8	5	7	9	22
Hobby	8	8	0	5	16
Sun	8	2	7	3	7
Diet_(nutrition)	7	4	5	1	2
Eating	7	5	3	0	0
Father	7	6	5	3	15
Future	7	7	2	0	0
Infant	7	6	5	0	0
Old_age	7	6	5	2	5
Pleasure	7	7	4	0	0
War	7	4	4	1	3

Childhood	6	4	6	0	0
Clothing	6	4	3	1	2
Hatred	6	5	5	0	0
House	6	4	3	5	12
Parent	6	6	4	1	2
Rain	6	3	4	0	0
Sadness	6	6	5	0	0
Birth	5	4	1	8	31
Disease	5	1	5	2	6
Experience	5	2	3	1	2
Learning	5	4	2	1	2
People	5	4	1	0	0
Pet	5	4	3	3	7
Purpose	5	4	2	1	2
Teacher	5	4	3	1	2
Bread	4	4	1	0	0
City	4	3	1	0	0
Computer	4	2	2	3	8
Forest	4	4	2	0	0
Friendship	4	4	1	15	68
Hospital	4	2	2	1	2
Light	4	3	2	1	2
Paper	4	2	4	0	0
Physical_fitness	4	2	3	1	2
Sport	4	1	3	0	0
Test_(assessment)	4	4	0	0	0
Tree	4	3	2	3	9
Automobile	3	1	3	2	4
Bed	3	3	1	0	0
Book	3	2	2	1	2
Cat	3	3	2	1	4
Clock	3	3	2	2	4
Dog	3	3	2	4	14
Flower	3	2	2	0	0
Heart	3	0	3	1	2
Home	3	3	1	6	22
Money	3	2	1	2	8
Party	3	3	0	2	5
School	3	2	3	10	40
Dream	2	2	1	1	2
Goal	2	1	2	0	0
Joy	2	1	2	5	18
Peace	2	2	1	1	2
World	2	2	0	0	0
Ground	1	1	0	3	7
Pen	1	1	0	0	0
Sea	1	1	1	1	2
Shoe	1	1	0	1	2
Sorrow	1	1	1	3	12
Summer	1	1	0	1	2
Telephone	1	0	1	1	2
Travel	1	0	1	1	2
Work	1	0	1	12	45
Chair	0	0	0	1	2
Environment	0	0	0	3	6
Fun	0	0	0	0	0
Goodness	0	0	0	0	0
Growing	0	0	0	1	2
Holiday	0	0	0	2	4
Living	0	0	0	21	68
Management	0	0	0	0	0
Study	0	0	0	4	12
<i>Sum of start/end concepts in hyperlinks or relationships unique to each observed concept</i>	652 (93 unique to collection of all observed concepts)	422 (85 unique to collection of all observed concepts)	422 (88 unique to collection of all observed concepts)	288 (75 unique to collection of all observed concepts if word brother can represent word sister)	968 (75 unique to collection of all observed concepts if word brother can represent word sister)
<i>Average value</i>	6.392157	4.137255	4.137255	2.843137	9.584158
<i>Median value</i>	5	3.5	3	1	2

Appendix I

Connectivity between 102 core concepts in the hyperlink network of the Wikipedia based on one fixed temporal version of the Wikipedia articles that have been available online in the Wikipedia in the beginning of March 2008 (last edited versions of articles and hyperlinks by date 3 March 2008).

<i>Observed hyperlink (all hyperlinks between 102 core concepts based on hyperlinks connecting corresponding Wikipedia articles)</i>		<i>Measurable properties concerning currently observed hyperlink</i>				
Start concept in hyperlink	End concept in hyperlink	Number of occurrences of hyperlink anchor in article text of start concept (several hyperlink anchors can exist in same article text)	Number of occurrences of hyperlink anchor for a hyperlink going into opposite direction (than original hyperlink) in article text of start concept of hyperlink going into opposite direction	Sum of occurrences of hyperlink anchor for hyperlinks going into original direction and hyperlink going into opposite direction	If between 102 core concepts there is a conceptual relationship mentioned by at least two students in concept maps drawn by students that corresponds to currently observed hyperlink then how many students have mentioned this relationship in concept maps (note that direction of relationship is not specified in concept maps)	If currently observed hyperlink departs from intro text section of article text of start concept a notation "from intro text section" is mentioned in this column
Biology	Evolution	9	1	10	less than 2	from intro text section
Human	Religion	9	1	10	less than 2	
Biology	Organism	8	2	10	less than 2	
Human	Philosophy	8	0	8	less than 2	
Dog	Pet	6	3	9	3	from intro text section
Book	Paper	5	1	6	less than 2	from intro text section
Father	Mother	5	2	7	6	from intro text section
Religion	Philosophy	5	2	7	less than 2	from intro text section
Time	Clock	5	4	9	less than 2	
Animal	Plant	4	2	6	less than 2	from intro text section
Biology	Animal	4	1	5	less than 2	
Clock	Time	4	5	9	less than 2	from intro text section
Death	Disease	4	1	5	4	from intro text section
Family	Marriage	4	3	7	less than 2	from intro text section
Hatred	Pleasure	4	1	5	less than 2	
Music	Time	4	0	4	less than 2	
Nature	Animal	4	1	5	8	
Sadness	Happiness	4	0	4	less than 2	from intro text section
Sadness	Pleasure	4	1	5	less than 2	
Sibling	Parent	4	1	5	less than 2	from intro text section
Water	Human	4	0	4	less than 2	from intro text section
Water	Oxygen	4	2	6	2	
Adolescence	Child	3	1	4	less than 2	
Adolescence	Childhood	3	1	4	less than 2	from intro text section

Atmosphere_of_Earth	Oxygen	3	0	3	less than 2	from intro text section
Biology	Plant	3	1	4	less than 2	
Cat	Dog	3	1	4	4	
Child	Childhood	3	2	5	less than 2	
Education	Philosophy	3	0	3	less than 2	from intro text section
Education	School	3	2	5	3	
Emotion	Sadness	3	3	6	less than 2	
Family	Mother	3	2	5	6	
Family	Sibling	3	2	5	2	
Future	Time	3	2	5	less than 2	
Health	Diet_(nutrition)	3	1	4	less than 2	
Health	Physical_fitness	3	1	4	2	
Human	Animal	3	1	4	3	
Human	City	3	0	3	less than 2	
Human	Love	3	0	3	4	
Love	Pleasure	3	1	4	less than 2	
Marriage	Family	3	4	7	less than 2	from intro text section
Nature	Organism	3	0	3	less than 2	
Nature	Plant	3	1	4	5	
Parent	Mother	3	2	5	less than 2	from intro text section
Pet	Dog	3	6	9	3	from intro text section
Plant	Flower	3	1	4	less than 2	
Plant	Forest	3	1	4	less than 2	
Plant	Tree	3	0	3	5	from intro text section
Rain	Plant	3	0	3	less than 2	
Religion	God	3	1	4	less than 2	
Sadness	Emotion	3	3	6	less than 2	
Tree	Water	3	0	3	less than 2	
Water	Rain	3	1	4	less than 2	
Water	Sea	3	1	4	2	from intro text section
Animal	Organism	2	0	2	less than 2	from intro text section
Atmosphere_of_Earth	Organism	2	0	2	less than 2	from intro text section
Biology	Human	2	0	2	less than 2	
Bread	Food	2	1	3	less than 2	
Childhood	Child	2	3	5	less than 2	from intro text section
Childhood	Infant	2	1	3	less than 2	from intro text section
Death	Diet_(nutrition)	2	1	3	less than 2	
Eating	Food	2	1	3	less than 2	from intro text section
Education	Adolescence	2	1	3	less than 2	
Education	Learning	2	2	4	less than 2	from intro text section
Emotion	Happiness	2	1	3	less than 2	
Emotion	Love	2	2	4	2	
Family	Father	2	1	3	7	
Father	Marriage	2	0	2	less than 2	from intro text section
Father	Parent	2	2	4	less than 2	from intro text section
Food	Animal	2	0	2	3	
Food	Plant	2	0	2	less than 2	
Food	Water	2	0	2	6	
Friendship	Love	2	2	4	8	
God	Nature	2	0	2	less than 2	
Hatred	Emotion	2	1	3	less than 2	
Hatred	Happiness	2	0	2	less than 2	
Hatred	Love	2	1	3	less than 2	
Hatred	Sadness	2	2	4	less than 2	
Health	Disease	2	0	2	2	from intro text section
Human	Adolescence	2	0	2	less than 2	
Human	Childhood	2	0	2	less than 2	
Human	Diet_(nutrition)	2	0	2	less than 2	
Human	Emotion	2	0	2	less than 2	

Human	Evolution	2	0	2	less than 2	
Human	Music	2	0	2	less than 2	
Human	Old_age	2	0	2	less than 2	
Human	War	2	0	2	less than 2	
Infant	Child	2	1	3	less than 2	from intro text section
Learning	Education	2	2	4	less than 2	from intro text section
Light	Sun	2	0	2	less than 2	
Light	Time	2	1	3	less than 2	
Love	Biology	2	0	2	less than 2	
Love	Emotion	2	2	4	2	from intro text section
Love	Friendship	2	2	4	8	
Marriage	Love	2	1	3	less than 2	from intro text section
Mother	Family	2	3	5	6	
Mother	Father	2	5	7	6	from intro text section
Mother	Marriage	2	0	2	less than 2	
Mother	Parent	2	3	5	less than 2	from intro text section
Mother	Sibling	2	2	4	less than 2	
Nature	Biology	2	1	3	3	
Nature	Human	2	0	2	4	from intro text section
Nature	Oxygen	2	0	2	less than 2	
Nature	Sun	2	0	2	3	
Organism	Biology	2	8	10	less than 2	from intro text section
Oxygen	Plant	2	1	3	less than 2	from intro text section
Oxygen	Water	2	4	6	2	
Parent	Father	2	2	4	less than 2	from intro text section
Parent	Human	2	0	2	less than 2	from intro text section
Party	Television	2	0	2	less than 2	
People	Human	2	0	2	less than 2	from intro text section
People	Philosophy	2	0	2	less than 2	
Pet	Cat	2	1	3	less than 2	
Philosophy	Religion	2	5	7	less than 2	
Plant	Animal	2	4	6	less than 2	
Plant	Light	2	0	2	less than 2	
Plant	Organism	2	1	3	less than 2	from intro text section
Pleasure	Emotion	2	1	3	less than 2	
Pleasure	Happiness	2	0	2	less than 2	from intro text section
Sadness	Hatred	2	2	4	less than 2	
Sadness	Love	2	1	3	less than 2	
School	Education	2	3	5	3	from intro text section
Sibling	Family	2	3	5	2	from intro text section
Sibling	Father	2	1	3	less than 2	
Sibling	Love	2	0	2	less than 2	from intro text section
Sibling	Mother	2	2	4	less than 2	
Sun	Oxygen	2	1	3	less than 2	from intro text section
Teacher	School	2	1	3	2	
Time	Future	2	3	5	less than 2	
Tree	Forest	2	1	3	less than 2	
War	Peace	2	1	3	less than 2	
Adolescence	Education	1	2	3	less than 2	
Adolescence	Infant	1	1	2	less than 2	
Adolescence	Old_age	1	1	2	less than 2	
Adolescence	Sport	1	0	1	less than 2	
Adolescence	Television	1	0	1	less than 2	
Animal	Atmosphere_of_Earth	1	1	2	less than 2	
Animal	Biology	1	4	5	less than 2	
Animal	Evolution	1	0	1	less than 2	
Animal	Human	1	3	4	3	

Animal	Nature	1	4	5	8	
Animal	Oxygen	1	0	1	less than 2	
Animal	Time	1	0	1	less than 2	
Animal	Water	1	0	1	less than 2	
Atmosphere_of_Earth	Animal	1	1	2	less than 2	
Atmosphere_of_Earth	Automobile	1	0	1	less than 2	
Atmosphere_of_Earth	Biology	1	1	2	less than 2	
Atmosphere_of_Earth	Evolution	1	0	1	less than 2	
Atmosphere_of_Earth	Nature	1	1	2	less than 2	
Atmosphere_of_Earth	Plant	1	1	2	less than 2	
Atmosphere_of_Earth	Time	1	0	1	less than 2	
Automobile	Oxygen	1	1	2	less than 2	
Bed	Dream	1	1	2	less than 2	
Bed	Hospital	1	0	1	less than 2	
Bed	Infant	1	0	1	less than 2	
Biology	Atmosphere_of_Earth	1	1	2	less than 2	
Biology	Health	1	1	2	less than 2	
Biology	Nature	1	2	3	3	
Biology	Time	1	0	1	less than 2	
Birth	Animal	1	0	1	less than 2	from intro text section
Birth	Death	1	0	1	13	
Birth	Mother	1	0	1	less than 2	from intro text section
Birth	Sun	1	0	1	less than 2	
Book	Music	1	0	1	less than 2	
Bread	Money	1	0	1	less than 2	
Bread	Paper	1	0	1	less than 2	from intro text section
Bread	Water	1	0	1	less than 2	from intro text section
Cat	Human	1	0	1	less than 2	from intro text section
Cat	Pet	1	2	3	less than 2	
Child	Adolescence	1	3	4	less than 2	
Child	Family	1	1	2	7	
Child	Infant	1	2	3	less than 2	
Child	Leisure	1	0	1	less than 2	
Child	Marriage	1	0	1	less than 2	
Child	Old_age	1	1	2	less than 2	
Child	Parent	1	1	2	less than 2	from intro text section
Child	Sibling	1	0	1	less than 2	
Childhood	Adolescence	1	3	4	less than 2	
Childhood	Old_age	1	1	2	less than 2	
City	Automobile	1	0	1	less than 2	
City	Rain	1	0	1	less than 2	
City	Religion	1	0	1	less than 2	
Clock	Computer	1	0	1	2	
Clock	Future	1	1	2	less than 2	
Clothing	Marriage	1	0	1	less than 2	
Clothing	Paper	1	1	2	less than 2	
Clothing	Religion	1	0	1	less than 2	from intro text section
Clothing	Television	1	0	1	less than 2	
Computer	Telephone	1	0	1	less than 2	
Computer	Television	1	0	1	4	
Death	Evolution	1	0	1	less than 2	
Death	Heart	1	0	1	less than 2	
Death	Human	1	0	1	3	
Death	Organism	1	0	1	less than 2	from intro text section
Death	Oxygen	1	0	1	less than 2	
Death	Physical_fitness	1	0	1	less than 2	
Death	War	1	0	1	3	
Diet_(nutrition)	Death	1	2	3	less than 2	from intro text section

Diet_(nutrition)	Health	1	3	4	less than 2	from intro text section
Diet_(nutrition)	Organism	1	0	1	less than 2	from intro text section
Diet_(nutrition)	Religion	1	0	1	less than 2	from intro text section
Disease	Death	1	4	5	4	from intro text section
Dog	Adolescence	1	0	1	less than 2	
Dog	Cat	1	3	4	4	
Dream	Bed	1	1	2	less than 2	
Dream	God	1	0	1	less than 2	
Eating	Animal	1	0	1	less than 2	from intro text section
Eating	Human	1	0	1	less than 2	from intro text section
Eating	Organism	1	0	1	less than 2	from intro text section
Eating	Plant	1	0	1	less than 2	from intro text section
Education	Biology	1	0	1	less than 2	
Education	Child	1	0	1	less than 2	
Education	Childhood	1	0	1	less than 2	
Education	Family	1	0	1	less than 2	
Education	Human	1	0	1	less than 2	
Education	Leisure	1	1	2	less than 2	
Education	Marriage	1	0	1	less than 2	
Education	Sibling	1	0	1	less than 2	
Education	Teacher	1	1	2	less than 2	
Emotion	Evolution	1	0	1	less than 2	from intro text section
Emotion	Experience	1	0	1	less than 2	from intro text section
Emotion	Hatred	1	2	3	less than 2	
Emotion	Joy	1	0	1	less than 2	
Emotion	Pleasure	1	2	3	less than 2	
Evolution	Biology	1	9	10	less than 2	from intro text section
Evolution	Organism	1	1	2	less than 2	
Evolution	Oxygen	1	0	1	less than 2	
Evolution	Philosophy	1	0	1	less than 2	
Evolution	Plant	1	0	1	less than 2	
Experience	Philosophy	1	0	1	less than 2	
Experience	Time	1	0	1	less than 2	
Family	Child	1	1	2	7	
Family	Leisure	1	1	2	less than 2	
Father	Family	1	2	3	7	
Father	Love	1	0	1	less than 2	
Father	Sibling	1	2	3	less than 2	
Flower	Evolution	1	0	1	less than 2	
Flower	Plant	1	3	4	less than 2	
Food	Bread	1	2	3	less than 2	
Food	Computer	1	0	1	less than 2	
Food	Death	1	0	1	less than 2	
Food	Diet_(nutrition)	1	0	1	less than 2	
Food	Eating	1	2	3	less than 2	from intro text section
Food	Health	1	1	2	3	
Food	Human	1	0	1	less than 2	
Food	School	1	0	1	less than 2	
Food	War	1	0	1	less than 2	
Forest	Flower	1	0	1	less than 2	
Forest	Plant	1	3	4	less than 2	
Forest	Rain	1	0	1	less than 2	
Forest	Tree	1	2	3	less than 2	from intro text section
Friendship	Adolescence	1	0	1	2	
Friendship	Animal	1	0	1	less than 2	
Friendship	Philosophy	1	0	1	less than 2	from intro text section
Future	Clock	1	1	2	less than 2	
Future	Death	1	0	1	less than 2	
Future	Evolution	1	0	1	less than 2	
Future	Human	1	0	1	less than 2	
Future	Philosophy	1	0	1	less than 2	

Future	Religion	1	0	1	less than 2	
Goal	Purpose	1	1	2	less than 2	
God	Father	1	0	1	less than 2	
God	Philosophy	1	1	2	less than 2	
God	Religion	1	3	4	less than 2	from intro text section
Ground	Philosophy	1	0	1	less than 2	
Happiness	Emotion	1	2	3	less than 2	from intro text section
Happiness	Joy	1	1	2	less than 2	from intro text section
Health	Biology	1	1	2	less than 2	
Health	Food	1	1	2	3	
Hobby	Book	1	0	1	less than 2	
Hobby	Eating	1	0	1	less than 2	
Hobby	Education	1	0	1	less than 2	
Hobby	Food	1	0	1	less than 2	
Hobby	House	1	0	1	less than 2	
Hobby	Leisure	1	0	1	3	from intro text section
Hobby	Plant	1	0	1	less than 2	
Hobby	Sport	1	0	1	less than 2	
Home	Family	1	0	1	9	from intro text section
Home	House	1	1	2	3	
Home	Love	1	0	1	less than 2	
Hospital	Disease	1	0	1	less than 2	
Hospital	Health	1	0	1	less than 2	
House	Family	1	0	1	3	from intro text section
House	Home	1	1	2	3	from intro text section
House	Pet	1	0	1	less than 2	
House	Television	1	0	1	less than 2	
Human	Clothing	1	0	1	less than 2	
Human	Family	1	0	1	4	
Human	God	1	0	1	less than 2	
Human	Happiness	1	0	1	less than 2	
Human	Health	1	0	1	less than 2	
Human	House	1	0	1	less than 2	
Human	Oxygen	1	0	1	less than 2	
Infant	Adolescence	1	1	2	less than 2	
Infant	Childhood	1	2	3	less than 2	
Infant	Health	1	0	1	less than 2	
Infant	Hospital	1	0	1	less than 2	
Infant	Old_age	1	1	2	less than 2	
Joy	Happiness	1	1	2	less than 2	
Learning	Experience	1	0	1	less than 2	from intro text section
Learning	Physical_fitness	1	0	1	less than 2	
Learning	Time	1	0	1	less than 2	
Leisure	Eating	1	0	1	less than 2	from intro text section
Leisure	Education	1	1	2	less than 2	from intro text section
Leisure	Family	1	1	2	less than 2	
Leisure	Marriage	1	1	2	less than 2	
Leisure	Sibling	1	0	1	less than 2	
Leisure	Television	1	0	1	2	
Leisure	Time	1	0	1	less than 2	from intro text section
Leisure	Work	1	0	1	less than 2	from intro text section
Light	Television	1	0	1	less than 2	
Love	Family	1	0	1	13	from intro text section
Love	Happiness	1	0	1	3	
Love	Hatred	1	2	3	less than 2	
Love	Marriage	1	2	3	less than 2	
Love	Philosophy	1	0	1	less than 2	
Love	Religion	1	0	1	less than 2	
Love	Sadness	1	2	3	less than 2	
Marriage	Death	1	0	1	less than 2	
Marriage	Emotion	1	0	1	less than 2	
Marriage	God	1	0	1	less than 2	

Marriage	Leisure	1	1	2	less than 2	
Marriage	Religion	1	0	1	less than 2	from intro text section
Marriage	Sibling	1	1	2	less than 2	
Money	Food	1	0	1	less than 2	
Money	Water	1	0	1	less than 2	
Mother	Human	1	0	1	less than 2	from intro text section
Mother	Leisure	1	0	1	less than 2	
Mother	Love	1	0	1	2	
Music	Religion	1	0	1	less than 2	
Music	Television	1	0	1	less than 2	
Nature	Atmosphere_of_Earth	1	1	2	less than 2	
Nature	Evolution	1	0	1	less than 2	
Nature	Time	1	0	1	less than 2	
Old_age	Adolescence	1	1	2	less than 2	
Old_age	Biology	1	0	1	less than 2	from intro text section
Old_age	Child	1	1	2	less than 2	
Old_age	Childhood	1	1	2	less than 2	
Old_age	Death	1	0	1	3	
Old_age	Infant	1	1	2	less than 2	
Organism	Evolution	1	1	2	less than 2	
Organism	Heart	1	0	1	less than 2	
Organism	Plant	1	2	3	less than 2	
Oxygen	Automobile	1	1	2	less than 2	
Oxygen	Disease	1	0	1	less than 2	
Oxygen	Heart	1	0	1	less than 2	
Oxygen	Philosophy	1	0	1	less than 2	
Oxygen	Rain	1	0	1	less than 2	
Oxygen	Sport	1	0	1	less than 2	
Oxygen	Sun	1	2	3	less than 2	
Paper	Book	1	5	6	less than 2	
Paper	Clothing	1	1	2	less than 2	
Parent	Birth	1	0	1	less than 2	from intro text section
Parent	Child	1	1	2	less than 2	
Parent	Sibling	1	4	5	less than 2	
Party	Family	1	0	1	less than 2	
Party	Music	1	0	1	less than 2	
Peace	Education	1	0	1	less than 2	
Peace	War	1	2	3	less than 2	
Pen	Paper	1	0	1	less than 2	from intro text section
People	Purpose	1	0	1	less than 2	
People	Religion	1	0	1	less than 2	
Pet	Animal	1	0	1	less than 2	from intro text section
Pet	People	1	0	1	less than 2	
Philosophy	God	1	1	2	less than 2	
Philosophy	Music	1	0	1	less than 2	
Physical_fitness	Diet_(nutrition)	1	0	1	less than 2	
Physical_fitness	Health	1	3	4	2	from intro text section
Plant	Atmosphere_of_Earth	1	1	2	less than 2	
Plant	Biology	1	3	4	less than 2	
Plant	Nature	1	3	4	5	
Plant	Oxygen	1	2	3	less than 2	
Plant	Time	1	0	1	less than 2	
Plant	Water	1	1	2	less than 2	
Pleasure	Hatred	1	4	5	less than 2	
Pleasure	Love	1	3	4	less than 2	
Pleasure	Music	1	0	1	less than 2	
Pleasure	Philosophy	1	0	1	less than 2	
Pleasure	Sadness	1	4	5	less than 2	
Purpose	Goal	1	1	2	less than 2	from intro text section
Purpose	God	1	0	1	less than 2	
Purpose	Happiness	1	0	1	less than 2	
Purpose	Philosophy	1	0	1	less than 2	
Rain	Sun	1	0	1	less than 2	
Rain	Water	1	3	4	less than 2	from intro text section

Religion	Evolution	1	0	1	less than 2	
Religion	Human	1	9	10	less than 2	
Religion	Sun	1	0	1	less than 2	
Sadness	Sorrow	1	1	2	less than 2	from intro text section
School	Teacher	1	2	3	2	from intro text section
Sea	Water	1	3	4	2	
Shoe	Clothing	1	0	1	2	
Sibling	Marriage	1	1	2	less than 2	
Sorrow	Sadness	1	1	2	less than 2	
Sport	Television	1	0	1	less than 2	
Summer	Plant	1	0	1	less than 2	
Sun	Plant	1	0	1	less than 2	
Teacher	Education	1	1	2	less than 2	
Teacher	Goal	1	0	1	less than 2	
Teacher	Learning	1	0	1	less than 2	
Test_(assessment)	Education	1	0	1	less than 2	from intro text section
Test_(assessment)	Music	1	0	1	less than 2	
Test_(assessment)	Philosophy	1	0	1	less than 2	
Test_(assessment)	Teacher	1	0	1	less than 2	
Time	Education	1	0	1	less than 2	
Time	God	1	0	1	less than 2	
Time	Light	1	2	3	less than 2	
Time	Philosophy	1	0	1	less than 2	from intro text section
Time	Religion	1	0	1	less than 2	from intro text section
Time	Television	1	0	1	less than 2	
Tree	Oxygen	1	0	1	less than 2	from intro text section
War	Disease	1	0	1	less than 2	
War	Hatred	1	0	1	less than 2	
War	Religion	1	0	1	less than 2	
Water	Biology	1	0	1	less than 2	
Water	Organism	1	0	1	less than 2	
Water	Plant	1	1	2	less than 2	
Water	Sun	1	0	1	less than 2	
Water	Time	1	0	1	less than 2	
Water	Travel	1	0	1	less than 2	
World	Experience	1	0	1	less than 2	from intro text section
World	Human	1	0	1	less than 2	from intro text section

Appendix J

Listing of all 212 hyperlinks belonging to “hyperlink network of 55 concepts” that was used in exploration experiment with students (n=49). All these 212 hyperlinks are connecting concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (containing 55 concepts including concept Human). All these 212 hyperlinks are shown here supplied with a relation statement for each hyperlink in English and its Finnish translation. In relation statement the start concept has been indicated with a notation starting with character string “A1” and ending with character string “A2” and the end concept has been indicated with a notation starting with character string “B1” and ending with character string “B2”. These notations helped to automatically highlight with different colors both start concept and end concept in relation statement when it was shown to the student during exploration experiment.

Relation statements have been extracted from the article of start concept, primarily taken around hyperlink pointing to end concept, but possibly with some modifications. Please note that due to lack of suitable phrase surrounding hyperlink anchor of start concept of hyperlink some of the relation statements are generated and synthesized based on other contextual text segments we identified relatively near the hyperlink anchor or possibly based on relation statement we managed to identify for another hyperlink going into opposite direction (i.e. for a hyperlink whose start concept is end concept of current hyperlink and end concept is start concept of current hyperlink). In column 3 relation statement is supplied with notation “(taken from other part of article)” if this relation statement has been generated and synthesized with this special method but this additional notation was not shown to the student.

Hyperlink		Relation statement (extracted from the article of start concept, primarily taken around hyperlink pointing to end concept, but possibly with some modifications)	
<i>Start concept in hyperlink</i>	<i>End concept in hyperlink</i>	<i>Relation statement in English (original language version)</i>	<i>Relation statement translated to Finnish</i>
Adolescence	Child	in A1adolescenceA2 B1childB2 develops sex characteristics	A1nuoruudessaA2 B1lapselleB2 kehittyy sukupuoliominaisuuksia
Adolescence	Education	in A1adolescenceA2 B1educationB2 of children changes from elementary school to secondary school (taken from other part of article)	A1nuoruudessaA2 lasten B1koulutusB2 siirtyy alakoulusta yläkouluun
Adolescence	Old_age	B1old ageB2 is a matured stage of personal development which contains also A1adolescenceA2 (taken from other part of article)	B1vanhuusB2 on kypsynyt vaihe yksilönkehityksessä johon myös A1nuoruusA2 kuuluu
Adolescence	Television	B1televisionB2 programs are popular amongst A1adolescentsA2	B1televisioB2-ohjelmat ovat suosittuja A1nuortenA2 keskuudessa
Animal	Biology	in nature B1biologyB2 has a central role for life such as A1animalsA2 (taken from other part of article)	luonnossa B1biologiallaB2 on keskeinen merkitys elämälle, kuten A1eläimilleA2
Animal	Human	when talking about A1animalsA2 it is often referred to other animals than B1humansB2	A1eläimistäA2 puhuttaessa usein viitataan muihin eläimiin kuin B1ihmisiinB2
Animal	Nature	B1natureB2 has a central role for A1animalsA2 (taken from other part of article)	B1luonnollaB2 on keskeinen merkitys A1eläimilleA2
Animal	Organism	A1animalsA2 are multicellular B1organismsB2	A1eläimetA2 ovat monisoluisia B1eliöitäB2
Animal	Oxygen	A1animalsA2 benefit from process in which the energy of sunlight helps to release B1oxygenB2 (taken from other part of article)	A1eläimetA2 hyötyvät siitä että auringonvalon energian avulla vapautuu B1happeaB2
Animal	Plant	A1animalsA2 generally digest food internally which separates them from B1plantsB2 (taken	A1eläimetA2 yleensä sulattavat ravinnon sisäisesti mikä erottaa ne

		from other part of article)	B1kasveistaB2
Animal	Water	A1animalsA2 benefit from plants which with carbon dioxide and B1waterB2 store the energy of sunlight (taken from other part of article)	A1eläimetA2 hyötyvät kasveista jotka hiilidioksidin ja B1vedenB2 avulla varastoivat auringonvalon energiaa
Automobile	Oxygen	Francois Rivaz designed the first A1automobileA2 that was fuelled by hydrogen and B1oxygenB2	Francois Rivaz suunnitteli ensimmäisen vetyä ja B1happeaB2 polttoaineena käyttäneen A1autonA2
Biology	Animal	zoology that belongs to A1biologyA2 involves the study of B1animalsB2 (taken from other part of article)	A1biologianA2 osana oleva eläintiede on B1eläimiinB2 kohdistuvaa tutkimusta
Biology	Health	A1biologyA2 is considered as a general effective factor to B1healthB2 (taken from other part of article)	A1biologiaA2 pidetään yleisenä vaikuttavana tekijänä B1terveyteenB2
Biology	Human	cell biology that belongs to A1biologyA2 researches multicellular organisms like B1humansB2	A1biologianA2 osana oleva solubiologia tutkii monisoluisia eliöitä, kuten B1ihmisiäB2
Biology	Nature	B1natureB2 has a central role for A1biologyA2 (taken from other part of article)	B1luonnollaB2 on keskeinen merkitys A1biologiassaA2
Biology	Organism	based on A1biologyA2 all B1organismsB2 descend from a common ancestor or gene pool (taken from other part of article)	A1biologianA2 perusteella kaikki B1eliötB2 periytyvät yhteisistä esivanhemmista tai geenijoukosta
Biology	Plant	botany that belongs to A1biologyA2 is the scientific study of B1plantsB2 (taken from other part of article)	A1biologianA2 osana oleva kasvitiede on B1kasvienB2 tieteellistä tutkimista
Birth	Animal	in A1birthA2 an offspring of an B1animalB2 is expelled from the body of its mother	A1syntymässäA2 B1eläimenB2 jälkeläinen poistuu äidin kehosta
Birth	Death	there are beliefs about a new A1birthA2 after B1deathB2 (taken from other part of article)	on uskomuksia uudelleen A1syntymisestäA2 B1kuolemanB2 jälkeen
Birth	Mother	in A1birthA2 an offspring of an animal is expelled from the body of its B1motherB2	A1syntymässäA2 eläimen jälkeläinen poistuu B1äidinB2 kehosta
Birth	Sun	there are beliefs that an individual's life is influenced by the positions of the B1SunB2 in the sky at the moment of A1birthA2	on uskomuksia että elämään vaikuttaa B1aurionB2 sijainti taivaalla A1syntymänA2 hetkellä
Cat	Dog	A1catsA2 do not hunt in groups as B1dogsB2 do	A1kissatA2 eivät saalista ryhmissä, kuten B1koiratB2
Cat	Human	A1catA2 is a crepuscular mammal that is often valued by B1humansB2	A1kissaA2 on hämärässä liikkuva nisäkäs, josta B1ihmisetB2 usein pitävät
Cat	Pet	some people keep A1catsA2 as B1petsB2	jotkut pitävät A1kissojaA2 B1lemmikkieläiminäB2
Child	Adolescence	B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2	B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu
Child	Family	according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life (taken from other part of article)	myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Child	Leisure	according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Child	Old_age	B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2 (taken from other part of article)	B1vanhuusB2 on kypsytynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu
Child	Parent	A1childA2 as a term may define a relationship with a B1parentB2 or authority (taken from other part of article)	A1lapsiA2 käsitteenä voi määritellä suhteen B1vanhempaanB2 tai auktoriteettiin
Child	Sibling	according to the declaration of	myös A1lapsiaA2 koskevan

		human rights that covers also A1childrenA2 everyone has right for B1brotherhoodB2 (taken from other part of article)	ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin
Clothing	Religion	A1clothingA2 is worn to reflect meaning of B1religionB2 (taken from other part of article)	A1vaatetustaA2 käytetään heijastamaan B1uskonnonB2 merkityksiä
Clothing	Television	in A1clothingA2 costume history serves as a topic of professional interest to costumers constructing for B1televisionB2 (taken from other part of article)	A1vaatetuksessaA2 pukujen historia on ammatillisesti kiinnostava puvustajille B1televisiossaB2
Computer	Telephone	personal A1computersA2 are becoming as common as the B1telephoneB2	henkilökohtaiset A1tietokoneetA2 ovat tulossa yhtä yleiseksi kuin B1puhelinB2
Computer	Television	personal A1computersA2 are becoming as common as the B1televisionB2	henkilökohtaiset A1tietokoneetA2 ovat tulossa yhtä yleiseksi kuin B1televisioB2
Death	Diet_(nutrition)	causes of A1deathA2 can be postponed by B1dietB2	syitä A1kuolemaanA2 voidaan lykätä B1ravinnollaB2
Death	Disease	many factors can contribute to an organism's A1deathA2, including B1diseaseB2	eliön A1kuolemaanA2 voivat vaikuttaa useat tekijät mukaan lukien B1sairaudetB2
Death	Heart	A1deathA2 was once defined as the cessation of beating of B1heartB2	aikoinaan A1kuolemaA2 määriteltiin B1sydämenB2 lyönnin pysähtymisenä
Death	Human	an autopsy is examination of a B1humanB2 corpse to determine the cause of a person's A1deathA2	ruumiinavaus on B1ihmisenB2 ruumiin tutkiminen A1kuolemanA2 syyn selvittämiseksi
Death	Organism	A1deathA2 is the end of the life of a biological B1organismB2	A1kuolemaA2 on biologisen B1eliönB2 elämän päättyminen
Death	Oxygen	a loss of homeostasis of body related to A1deathA2 causes loss of B1oxygenB2	A1kuolemaanA2 liittyvä elimistön tasapainon menetys aiheuttaa B1hapenB2 puutetta
Death	War	B1warB2 can be considered as a situation whereby A1deathA2 assumes absolute value (taken from article War)	B1sotaaB2 voidaan pitää tilanteena, jossa A1kuolemaA2 saa ehdottoman aseman
Diet_(nutrition)	Death	A1dietaryA2 habits and choices play a significant role in prevalenceTARKISTA of B1deathB2	A1ravintoonA2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1kuolemanB2 esiintyvyyteen
Diet_(nutrition)	Health	A1dietaryA2 habits and choices play a significant role in B1healthB2	A1ravintoonA2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1terveyteenB2
Diet_(nutrition)	Organism	the A1dietA2 is the sum of food consumed by an B1organismB2	A1ravintoA2 on kokonaisuus ruoasta, jonka B1eliöB2 nauttii
Diet_(nutrition)	Religion	A1dietaryA2 habits and choices play a significant role in B1religionB2	A1ravintoonA2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1uskonnolleB2
Disease	Death	A1diseaseA2 is often used to refer to a uncomfortable condition possibly leading to B1deathB2	A1sairaudellaA2 viitataan usein epämiellyttävään mahdollisesti B1kuolemaanB2 johtavaan olotilaan
Dog	Adolescence	B1adolescenceB2 for most domestic A1dogsA2 is around age of 12 to 15 months	B1nuoruusB2vaihe useimmille kesyA1koirilleA2 on 12-15 kuukauden iässä
Dog	Cat	unlike the B1catB2 the A1dogA2 is not dependent on meat based protein in diet	toisin kuin B1kissaB2 A1koiraA2 ei ole riippuvainen lihaperäisestä proteiinista ravinnossa
Dog	Pet	the domestic A1dogA2 has been one of the most widely-kept working animals and B1petsB2 in human history	kesyA1koiraA2 on ollut eräs yleisimpiä työ- ja B1lemmikkieläimiäB2 ihmisen historiassa
Education	Adolescence	A1educationA2 in secondary school occurs during B1adolescenceB2	yläluokilla tarjottava A1koulutusA2 tapahtuu B1nuoruudenB2 aikana

Education	Biology	educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2 (taken from other part of article)	A1koulutustaA2 koskeva kasvatuspsykologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2
Education	Child	A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are	A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat
Education	Family	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Education	Human	A1educationA2 is a means to foster future development of B1humansB2	A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittymistä
Education	Learning	A1educationA2 encompasses teaching and B1learningB2 specific skills	A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2
Education	Leisure	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Education	School	progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate (taken from other part of article)	A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa
Education	Sibling	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2 (taken from other part of article)	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin
Education	Teacher	in A1educationA2 informal relationships can be established between B1teachersB2 and students (taken from other part of article)	A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä
Emotion	Experience	different A1emotionsA2 are associated with relatively distinct subjective B1experienceB2	erilaisia A1tunteitaA2 liittyy suhteellisen erillisiin omakohtaisiin B1kokemuksiinB2
Emotion	Happiness	list of basic A1emotionsA2 devised by Paul Ekman contains B1happinessB2 (taken from other part of article)	Paul Ekmanin ehdottama luettelo perusA1tunteistaA2 sisältää B1onnellisuudenB2
Emotion	Joy	according to Rober Plutchik B1joyB2 belongs to eight primary A1emotionsA2 (taken from other part of article)	Robert Plutchikin mukaan kahdeksaan ensisijaiseen A1tunteeseenA2 kuuluu B1iloB2
Emotion	Love	human A1emotionA2 of B1loveB2 is proposed to have evolved from the care of offspring	ihmisen B1rakkaudenB2 A1tunteenA2 on ehdotettu kehittyneen jälkeläisistä huolehtimisesta
Family	Child	A1familyA2 serves to give social orientation for B1childrenB2 (taken from other part of article)	A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti
Family	Father	concerning A1familyA2 a B1fatherB2 is a male parent (taken from other part of article)	A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi
Family	Leisure	according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2
Family	Mother	concerning A1familyA2 a B1motherB2 is a female parent (taken from other part of article)	A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi
Family	Sibling	in A1familyA2 a B1siblingB2 is a child of the same parents (taken from other part of article)	A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat
Father	Family	like B1familyB2 also role of A1fatherA2 can be considered to implement ruling (taken from other part of article)	kuten B1perhettäB2, myös A1isänA2 roolia voidaan pitää hallinnan ilmentäjinä

Father	Love	B1loveB2 belongs to relationships concerning A1fatherA2 (taken from other part of article)	A1isääA2 koskeviin ihmissuhteisiin kuuluu B1rakkausB2
Father	Mother	previously social rules determined who would be regarded as a A1fatherA2 i.e. the husband of the B1motherB2	ennen sosiaaliset säännöt määräisivät kenet katsottiin A1isäksiA2 eli B1äidinB2 mieheksi
Father	Parent	A1fatherA2 is a male B1parentB2 of an offspring	A1isääA2 on jälkeläisen miespuolinen B1vanhempiB2
Father	Sibling	concerning A1fatherA2 the B1siblingsB2 belong to the closest members of family (taken from other part of article)	A1isäänA2 liittyviin lähimpiin perheenjäseniin kuuluvat B1sisaruksetB2
Food	Animal	meat is an example of A1foodA2 directly coming from an B1animalB2 (taken from other part of article)	liha on esimerkki A1ruoastaA2 joka saadaan suoraan B1eläimestäB2
Food	Computer	control systems based on B1computersB2 can improve safety of A1foodA2	B1tietokoneisiinB2 perustuvat valvontajärjestelmät voivat parantaa A1ruoanA2 turvallisuutta
Food	Death	habits of consuming A1foodA2 play a significant role in the prevalence of B1deathB2	A1ruoanA2 käyttötottumuksilla on huomattava merkitys B1kuolemanB2 esiintymiseen
Food	Diet_(nutrition)	in A1foodA2 inorganic substances, like water, are important part of human B1dietB2 (taken from other part of article)	A1ruoassaA2 epäorgaaniset aineet, kuten vesi, ovat tärkeä osa ihmisen B1ravintoaB2
Food	Health	habits of consuming A1foodA2 play a significant role in the B1healthB2	A1ruoanA2 käyttötottumuksilla on huomattava merkitys B1terveyteenB2
Food	Human	the listing of A1foodA2stuffs include any substance ingested by B1humansB2	luettelo A1ruokaA2-aineista sisältää kaikenlaisia aineita, joita B1ihmisetB2 nauttivat ravinnoksi
Food	Plant	Many B1plantsB2 or their parts are eaten as A1foodA2.	useita B1kasvejaB2 tai niiden osia syödään A1ruokanaA2
Food	School	concerning A1foodA2 in out-of-home dining 6.6% of expenditures were based on B1schoolsB2 (taken from other part of article)	kodin ulkopuolisessa A1ruoanA2 nauttimisessa 6,6 prosenttia kuluista tapahtuu B1kouluissaB2
Food	War	production of A1foodA2 is influenced by international organizations and B1warB2	A1ruoanA2 tuotantoon vaikuttavat kansainväliset järjestöt ja B1sodanB2käynti
Food	Water	in A1foodA2 inorganic substances, like B1waterB2, are important part of human diet (taken from other part of article)	A1ruoassaA2 epäorgaaniset aineet, kuten B1vesiB2, ovat tärkeä osa ihmisen ravintoa
Friendship	Adolescence	A1friendshipsA2 are often the most important human relationships of the emotional life in B1adolescenceB2 (taken from other part of article)	A1ystävyyttäA2suhteet ovat usein tärkeimpiä tunne-elämän ihmissuhteita B1nuoruudessaB2
Friendship	Animal	in interpersonal relationships A1friendshipsA2 are found also among B1animalsB2 with high intelligence (taken from other part of article)	yksilöiden välisissä suhteissa A1ystävyyttäA2 esiintyy myös älykkäillä B1eläimilläB2
Friendship	Love	concerning A1friendshipA2 B1loveB2 is above all other motives as an inspiration (taken from other part of article)	A1ystävyyteenA2 liittyen B1rakkausB2 on kaikkien muiden motiivien yläpuolella innoittaja
God	Father	interpretation of A1godA2 as a B1fatherB2 is common in monotheistic Western culture (taken from other part of article)	yksijumalisessa länsimaisessa kulttuurissa tulkinta A1jumalastaA2 B1isäB2hahmona on yleinen
God	Nature	concerning B1natureB2 questions about the	B1luontoaB2 koskien kysymykset A1jumalanA2

		characteristics of A1godA2 are non-empirical and are domain of theology (taken from other part of article)	olemuksesta ovat ei-empiirisiä ja kuuluvat teologiaan
God	Religion	a A1godA2 most commonly refers to the deity worshiped by B1religionsB2	A1jumalaA2 useimmin viittaa yliluonnolliseen hahmoon, jota palvotaan B1uskonnoissaB2
Happiness	Emotion	A1happinessA2 is B1emotionB2 covering experiences ranging from satisfaction to joy (taken from other part of article)	A1onnellisuusA2 on B1tunneB2tila kattaen kokemuksia tyytyväisyydestä iloon
Happiness	Joy	A1happinessA2 is emotion covering experiences ranging from satisfaction to B1joyB2	A1onnellisuusA2 on tunnetila kattaen kokemuksia tyytyväisyydestä B1iloonB2
Health	Biology	A1healthA2 research builds primarily on the basic sciences like B1biologyB2 (taken from other part of article)	A1terveyttäA2 koskeva tutkimus rakentuu pääasiallisesti perustieteisiin, kuten B1biologiaanB2
Health	Diet_(nutrition)	bodily A1healthA2 is the result of e.g. regular proper B1dietB2	elimistön A1terveysA2 on seurausta mm. kunnollisesta B1ravinnostaB2
Health	Disease	A1healthA2 is a state of complete well-being and not merely the absence of B1diseaseB2	A1terveysA2 on kokonaisvaltaista hyvinvointia, eikä pelkästään B1sairaudenB2 puutetta
Health	Food	concerning A1healthA2 food pyramid is a general nutrition guide for B1foodB2 consumption (taken from other part of article)	A1terveyttäA2 koskeva ruokapyramidi on yleinen ravitsemusopas B1ruoanB2 kulutukselle
Home	Family	A1homeA2 is a place where a B1familyB2 lives together	A1kotiA2 on paikka, missä B1perheB2 asuu yhdessä
Home	House	B1houseB2 or residential dwelling is often referred to as a A1homeA2	B1taloonB2 tai asuntoon viitataan usein A1kotinaA2
Home	Love	A1homeA2 is a place where people that one B1lovesB2 becomes the focus (taken from other part of article)	A1kotiA2 on paikka, missä B1rakkaudenB2 kohteena olevat ihmiset saavat huomiota
House	Family	concerning A1houseA2 a household is most commonly a B1familyB2 unit of some kind	A1taloonA2 liittyen kotitalous on useimmin jonkinlainen B1perheB2yksikkö
House	Home	concerning A1houseA2 people generally call any building they routinely occupy B1homeB2	A1taloonA2 liittyen ihmiset kutsuvat usein pysyvää asuinpaikkaansa B1kodiksiB2
House	Pet	human interest in building A1housesA2 for animals does not stop at the domestic B1petB2	ihmisten kiinnostus rakentaa A1talojaA2 eläimille ei rajoitu vain B1lemmikkieläimiinB2
House	Television	parts of A1houseA2 often include B1televisionB2 room (taken from other part of article)	A1talonA2 osiin tyypillisesti kuuluu B1televisiollaB2 varustettu huone
Human	Adolescence	A1humanA2 life span can be split into a number of stages like B1adolescenceB2	A1ihmisenA2 elämänkaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2
Human	Animal	advent of agriculture by A1humansA2 led to domestication of B1animalsB2 (taken from other part of article)	A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesyttämiseen
Human	Clothing	A1humansA2 are the only species known to B1clotheB2 themselves	A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2
Human	Diet_(nutrition)	concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2	A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristötekijät, kuten B1ravintoB2
Human	Emotion	concerning A1humansA2 motivation is connected to B1emotionsB2 (taken from other part of article)	A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2
Human	Family	A1humansA2 create complex	A1ihmisetA2 muodostavat

		social structures such as B1familiesB2	monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2
Human	God	concerning A1humanA2 religions a common source for answers to questions are beliefs in B1godB2 (taken from other part of article)	A1ihmistenA2 harjoittamissa uskonnoissa vastauksia kysymyksiin saadaan uskomuksista B1jumalaanB2
Human	Happiness	B1happinessB2 is a A1humanA2 emotional condition	B1onnellisuusB2 on A1ihmisenA2 tunnetila
Human	Health	the best condition for A1humanA2 can be considered mental and physical B1healthB2 (taken from other part of article)	A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2
Human	House	concerning A1humansA2 habitat and population influence characteristics of B1housesB2 (taken from other part of article)	A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen
Human	Love	concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2 (taken from other part of article)	A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2
Human	Music	concerning A1humansA2 art is connected to B1musicB2 (taken from other part of article)	A1ihmisenA2 harjoittamaan taiteeseen liittyy B1musiikkiB2
Human	Old_age	A1humanA2 life span can be split into a number of stages like B1old ageB2	A1ihmisenA2 elämänskaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2
Human	Oxygen	A1humanA2 body contains 25.5 percent B1oxygenB2 (taken from other part of article)	A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia
Human	Religion	A1humansA2 are noted for their desire seeking explanations through B1religionB2	A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta
Human	War	B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources (taken from other part of article)	A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2
Joy	Happiness	A1joyA2 is an emotion of great B1happinessB2	A1iloA2 on tunne suuresta B1onnellisuudestaB2
Learning	Education	A1learningA2 is the goal of B1educationB2 (taken from other part of article)	A1oppiminenA2 on B1koulutuksenB2 tavoite
Learning	Experience	A1learningA2 is the product of B1experienceB2 (taken from other part of article)	A1oppiminenA2 on seurausta B1kokemuksestaB2
Leisure	Education	A1leisureA2 is the period of discretionary time outside compulsory activities such as B1educationB2 (taken from other part of article)	A1vapaa-aikaaA2 on omaehtoinen ajanjakso pakollisten tehtävien, kuten B1koulutuksenB2, ulkopuolella
Leisure	Family	according to the declaration of human rights that covers also A1leisureA2 everyone has right for B1familyB2 life	myös A1vapaa-aikaaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus oikeus B1perheB2-elämään
Leisure	Sibling	according to the declaration of human rights that covers also A1leisureA2 everyone has right for B1brotherhoodB2 (taken from other part of article)	myös A1vapaa-aikaaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin
Leisure	Television	passive A1leisureA2 activities are those in which a person does not exert any significant physical or mental energy, such as watching B1televisionB2	passiivisissa A1vapaa-ajanA2 tehtävissä, kuten B1televisionB2 katselussa, ei käytetä merkittävästi voimia
Leisure	Work	A1leisureA2 is a period of time spent out of B1workB2	A1vapaa-aikaaA2 on ajanjakso, joka käytetään ilman B1työtäB2
Light	Sun	examples of A1lightA2 source include the radiation emitted by the chromosphere of the B1SunB2 (taken from other part of article)	esimerkki A1valonA2lähteestä on B1auringonB2 koromofääristä lähtevä säteily
Light	Television	phenomena of phosphorescence	katodisädeputkeen

		is used in cathode ray tube B1televisionsB2 for producing A1lightA2 (taken from other part of article)	perustuvissa B1televisioissaB2 käytetään fosforensi-ilmiötä A1valonA2 synnyttämisessä
Love	Biology	according to B1biologyB2 there are two major drives in A1loveA2: sexual attraction and attachment	B1biologianB2 perusteella A1rakkaudelleA2 on kaksi vaikutinta: seksuaalinen vetovoima ja kiintymys
Love	Emotion	A1loveA2 can describe an intense feeling of affection, an B1emotionB2 or an emotional state (taken from other part of article)	A1rakkausA2 voi tarkoittaa kiihkeää kiintymystä, B1tunnettaB2 tai tunnetilaa
Love	Family	A1loveA2 has many different meanings ranging to something one would die for, like B1familyB2 (taken from other part of article)	A1rakkaudellaA2 on eri merkityksiä ulottuen johonkin, jonka puolesta kuolla, kuten B1perheB2
Love	Friendship	concerning A1loveA2 B1friendshipB2 means the spirit between friends (taken from other part of article)	A1rakkauteenA2 liittyen B1ystävyydenB2 merkitsee ystävien välillä vallitsevaa yhteishenkeä
Love	Happiness	A1loveA2 is connected to emotions about B1happinessB2 (taken from other part of article)	A1rakkauteenA2 liittyy tunteita B1onnellisuudestaB2
Love	Religion	throughout history, philosophy and B1religionB2 have done the most speculation on the phenomenon of A1loveA2	läpi historian filosofia ja B1uskontoB2 ovat eniten spekuloineet A1rakkauttaA2 ilmiöllä
Mother	Family	according to the declaration of human rights that covers also A1mothersA2 everyone has right for B1familyB2 life (taken from other part of article)	myös A1äitejäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Mother	Father	an adoptive A1motherA2 is the biologically unrelated wife of a child's B1fatherB2 (taken from other part of article)	adoptioA1äitiA2 on ei- biologinen vaimo lapsen B1isälleB2
Mother	Human	in the case of a mammal such as a B1humanB2, the biological A1motherA2 gestates a fertilized ovum	nisäkkäillä, kuten B1ihmiselläB2, biologinen A1äitiA2 kasvattaa hedelmöitetyn munasolun
Mother	Leisure	according to the declaration of human rights that covers also A1mothersA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1äitejäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Mother	Love	concerning A1motherA2 B1loveB2 belongs to relationships of family (taken from other part of article)	A1äitiinA2 liittyen B1rakkausB2 kuuluu perheen ihmissuhteisiin
Mother	Parent	A1motherA2 is a biological or social female B1parentB2 of an offspring	A1äitiA2 on biologinen tai sosiaalinen naispuolinen B1vanhempiB2 lapselle
Mother	Sibling	concerning A1motherA2 B1siblingsB2 belong to members of immediate family (taken from other part of article)	A1äitiinA2 liittyen lähimpiin perheenjäseniin kuuluvat B1sisaruksetB2
Music	Religion	A1musicA2 is performed in rituals such as B1religious processionsB2	A1musiikkiaA2 esitetään rituaaleissa, kuten B1uskontoonB2 liittyvissä seremonioissa
Music	Television	live A1musicA2 can be broadcast over the B1televisionB2	elävää A1musiikkiaA2 voidaan lähettää B1televisionB2 kautta
Nature	Animal	in A1natureA2 properties common to organisms, such as B1animalsB2, are that they are cellular (taken from other part of article)	A1luontoonA2 liittyen eliöille, kuten B1eläimilleB2, yleisiä ominaisuuksia on koostuminen soluista
Nature	Biology	in A1natureA2 B1biologyB2 has a central role for life	A1luonnossaA2 B1biologiassaB2 on keskeinen merkitys elämälle
Nature	Human	in A1natureA2 wilderness is generally defined as an environment that has not been directly modified by B1humanB2 (taken from other part of article)	A1luonnossaA2 erämaana pidetään ympäristöä, jota B1ihminenB2 ei ole suoraan muokannut

Nature	Organism	in A1natureA2 biological manifestation of life concerning B1organismsB2 is characterized by organization (taken from other part of article)	A1luonnossaA2 B1eliötäB2 koskeva elämä ilmenee biologisesti mm. järjestäytymisenä
Nature	Oxygen	in A1natureA2 dry air consists of 21 percent B1oxygenB2 (taken from other part of article)	A1luonnossaA2 kuiva ilma sisältää 21 prosenttia B1happeaB2
Nature	Plant	in A1natureA2 properties common to organisms, such as B1plantsB2, are that they are cellular (taken from other part of article)	A1luonnossaA2 eliöille, kuten B1kasveilleB2, yleisiä ominaisuuksia on koostuminen soluista
Nature	Sun	concerning A1natureA2 one part of the Earth is more exposed to the rays of the B1SunB2 (taken from other part of article)	A1luontoonA2 liittyen osa maapallosta on enemmän altistettuna B1auringonB2 säteille
Old_age	Adolescence	B1adolescenceB2 is a legally important stage in personal development like A1old ageA2 (taken from other part of article)	B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, kuten A1vanhuusA2
Old_age	Biology	part of B1biologyB2 related to A1ageingA2 is called senescence (taken from other part of article)	A1vanhuuteenA2 liittyvää B1biologianB2 osa-aluetta kutsutaan seneskenssiksi
Old_age	Child	B1childB2 is a legally important stage in personal development like also A1old ageA2 (taken from other part of article)	B1lapsiB2 on oikeudellisesti tärkeässä yksilönkehityksen vaiheessa, jollainen on myös A1vanhuusA2
Old_age	Death	A1old ageA2 is a stage of life preceding B1deathB2 (taken from other part of article)	A1vanhuusA2 on B1kuolemaaB2 edeltävä elämänvaihe
Organism	Biology	in B1biologyB2 an A1organismA2 is an individual living system	B1biologiassaB2 A1eliöA2 on itsenäinen elävä järjestelmä
Organism	Heart	A1organismsA2 have organs to produce a particular function such as the pumping of the blood by the B1heartB2 (taken from other part of article)	A1eliölläA2 on elimiä tiettyjen toimintojen tuottamiseksi, kuten veren pumppaaminen B1sydämelläB2
Organism	Plant	concerning A1organismsA2 about 500 million years ago, B1plantsB2 and fungi colonized the land (taken from other part of article)	A1eliöihinA2 liittyen noin 500 miljoona vuotta sitten B1kasvitB2 ja sienet valloittivat maa-alueet
Oxygen	Automobile	near the earth's surface ozone consisting of A1oxygenA2 is a pollutant formed from B1automobileB2 exhaust (taken from other part of article)	A1hapestastaA2 koostuva otsoni on maan pinnalla saaste, joka syntyy B1autojenB2 pakokaasuista
Oxygen	Disease	A1oxygen therapy is used to treat B1diseasesB2 that impair the ability to use gaseous oxygen (taken from other part of article)	A1happiA2terapiaa käytetään B1sairauksienB2 hoitoon, jotka vaikeuttavat hapen käyttöä
Oxygen	Heart	A1oxygen therapy is used to treat B1heartB2 disorders (taken from other part of article)	A1happiA2terapiaa käytetään B1sydämenB2 häiriöiden hoitoon
Oxygen	Plant	A1oxygenA2 in the form of O2 is produced from water e.g. by B1plantsB2 during photosynthesis	A1happiA2 muodossa O2 syntyy vedestä mm. B1kasvienB2 yhteyttämisen kautta
Oxygen	Sun	about 0.87 percent of the B1Sun'sB2 mass is from A1oxygenA2	noin 0,87 prosenttia B1auringonB2 massasta on A1happeaA2
Oxygen	Water	B1waterB2 (H2O) is the oxide of hydrogen and the most familiar A1oxygenA2 compound	B1vesiB2 (H2O) on vedyn oksidi ja yleisin A1happiA2yhdiste
Parent	Birth	mother is a A1parentA2 who gives B1birthB2 to an offspring (taken from other part of article)	äiti on A1vanhempiA2, joka synnyttämällä toteuttaa jälkeläisen B1syntymisenB2
Parent	Child	mother is the biological or social female A1parentA2 of a B1childB2	äiti on biologinen tai sosiaalinen naispuolinen A1vanhempiA2 B1lapselleB2
Parent	Father	B1fatherB2 is a A1parentA2 who sires an offspring (taken from other part of article)	B1isäB2 on A1vanhempiA2, joka hoitaa jälkeläistä

Parent	Human	concerning A1parentsA2 in the case of B1humansB2 the mother gestates her child in the uterus (taken from other part of article)	A1vanhempiinA2 liittyen B1ihmisenB2 tapauksessa biologinen äiti kasvattaa lasta kohdussaan
Parent	Mother	B1motherB2 is a A1parentA2 who nurtures an offspring (taken from other part of article)	B1äitiB2 on A1vanhempiA2, joka hoitaa jälkeläistä
Parent	Sibling	B1siblingsB2 compete about A1parentalA2 investments (taken from other part of article)	B1sisaruksetB2 kilpailevat A1vanhempiensaA2 investoinnista hyvinvointinsa lisäämiseksi
Peace	Education	A1peacefulA2 development can be a set of many different elements such as B1educationB2	A1rauhaaA2 tukeva kehitys voi koostua useasta tekijästä, kuten B1koulutuksestaB2
Peace	War	concerning A1peaceA2 democracies rarely make B1warB2 against each other (taken from other part of article)	A1rauhaanA2 liittyen demokraatit käyvät harvoin B1sotiaB2 toisiaan vastaan
Pet	Animal	A1petA2 is an B1animalB2 kept for companionship	A1lemmikkieläinA2 on B1eläinB2, jota pidetään seuraksi
Pet	Cat	only a small number of species of mammals like B1catB2 is practical as a A1petA2 (taken from other part of article)	vain pieni osa nisäkäslajeista, kuten B1kissaB2, on käytännöllisiä A1lemmikkieläimiksiA2
Pet	Dog	only a small number of species of mammals like B1dogB2 is practical as a A1petA2 (taken from other part of article)	vain pieni osa nisäkäslajeista, kuten B1koiraB2, on käytännöllisiä A1lemmikkieläimiksiA2
Plant	Animal	fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2 (taken from other part of article)	sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2
Plant	Biology	concerning A1plantsA2 in nature B1biologyB2 has a central role for life (taken from other part of article)	A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle
Plant	Light	most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide (taken from other part of article)	useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoB2 ja hiilidioksidia
Plant	Nature	in B1natureB2 human has contributed to the extinction of many A1plantsA2 (taken from other part of article)	B1luonnossaB2 ihminen on vaikuttanut useiden A1kasvienA2 sukupuuttoon
Plant	Organism	A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees	A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita
Plant	Oxygen	concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2 (taken from other part of article)	A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakehää, jossa on nykyisin 21 prosenttia B1happeaB2
Plant	Tree	among A1plantsA2 conifers are dominant B1treesB2 (taken from other part of article)	A1kasvienA2 joukossa paljassiemensiset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä
Plant	Water	growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2 (taken from other part of article)	A1kasvienA2 kasvu määräytyy myös ympäristötekijöistä, kuten saatavilla olevasta B1vedestäB2
Religion	God	A1religionA2 is related to awareness of B1GodB2 through direct personal experience (taken from other part of article)	A1uskontoonA2 liittyy tietoisuus B1jumalastaB2 suoran henkilökohtaisen kokemuksen kautta
Religion	Human	concerning A1religionA2 B1humansB2 have methods which attempt to answer fundamental questions (taken from other part of article)	A1uskontoaA2 koskien B1ihmisilläB2 on menetelmiä vastauksen saamiseksi perimmäisiin kysymyksiin
Religion	Sun	concerning A1religionA2 Isaac Newton believed that the planets	A1uskontoonA2 liittyen Isaac Newton uskoi, että

		revolve about the B1SunB2 and credited God with the design (taken from other part of article)	planeetat pyörivät B1auringonB2 ympäri jumalan suunnittelutyön seurauksena
School	Education	concerning A1schoolA2 most countries have a system of B1educationB2 which is compulsory (taken from other part of article)	A1kouluunA2 liittyen useimmilla valtioilla on B1koulutusB2järjestelmä, joka on pakollinen
School	Teacher	A1schoolA2 is an institution designed to allow students to learn under the supervision of B1teacherB2 (taken from other part of article)	A1kouluA2 on laitos, joka on suunniteltu, jotta opiskelijat voivat oppia B1opettajanB2 ohjauksessa
Sea	Water	A1seaA2 is a large expanse of saline B1waterB2 (taken from other part of article)	A1meriA2 on suuri alue suolaista B1vettäB2
Sibling	Family	A1siblingA2 bond is influenced by factors such as experiences outside the B1familyB2	suhde A1sisarustenA2 välillä riippuu esim. kokemuksista B1perheenB2 ulkopuolella
Sibling	Father	half sibling that shares the same B1fatherB2 is known as an agnate A1siblingA2	sisarpuolta, joka jakaa saman isän, voidaan kutsua B1isänB2 puolelta tulevaksi A1sisarukseksiA2
Sibling	Love	concerning A1siblingsA2 closeness may be marked with strong emotions such as B1loveB2 (taken from other part of article)	A1sisaruksiinA2 liittyen läheisyyteen voi kuulua voimakkaita tunteita, kuten B1rakkauttaB2
Sibling	Mother	half sibling that shares the same B1motherB2 is known as a uterine A1siblingA2	sisarpuolta, joka jakaa saman äidin, voidaan kutsua B1äidinB2 puolelta tulevaksi A1sisarukseksiA2
Sibling	Parent	A1siblingA2 is brother or sister with whom a person shares at least one B1parentB2 (taken from other part of article)	henkilön A1sisarusA2 on veli tai sisko, jonka kanssa hän jakaa ainakin yhden B1vanhemmanB2
Sun	Oxygen	surface composition of the A1SunA2 consists of hydrogen, helium and trace quantities of other elements like B1oxygenB2 (taken from other part of article)	A1auringonA2 pinta koostuu vedystä, heliumista ja pienistä määristä muita aineita, kuten B1happeaB2
Sun	Plant	photosynthesis by B1plantsB2 captures A1sunA2light and converts it to chemical form (taken from other part of article)	B1kasvienB2 yhteyttäminen kerää A1auringonA2valoa ja muuntaa sen kemialliseen muotoon
Teacher	Education	in B1educationB2 A1teachersA2 facilitate learning of students (taken from other part of article)	B1koulutuksessaB2 A1opettajatA2 helpottavat opiskelijoiden oppimista
Teacher	Learning	the objective for a A1teacherA2 is typically to teach a course of study and B1learningB2 skills (taken from other part of article)	A1opettajanA2 tavoitteena on usein opettaa kurssi sekä B1oppimisenB2 taitoja
Teacher	School	in education A1teachersA2 facilitate learning of students in B1schoolB2 (taken from other part of article)	koulutuksessa A1opettajatA2 helpottavat opiskelijoiden oppimista B1koulussaB2
Tree	Oxygen	A1treesA2 have been found to play an important role in producing B1oxygenB2 (taken from other part of article)	A1puillaA2 on havaittu olevan tärkeä tehtävä B1hapenB2 tuottamisessa
Tree	Water	roots of a A1treeA2 are generally embedded in earth absorbing B1waterB2 from the soil (taken from other part of article)	A1puidenA2 juuret sijaitsevat yleensä maan sisässä imien B1vettäB2 maaperästä
War	Disease	growth of population is limited by A1warA2 as well as B1diseasesB2 (taken from other part of article)	A1sotaA2 rajoittaa väestönkasvua, kuten myös B1sairaudetB2
War	Peace	theories of A1warA2 must explain also B1peaceB2 (taken from other part of article)	A1sotaaA2 koskevien teorioiden tulee selittää myös B1rauhaaB2
War	Religion	acceptance of A1warA2 is inculcated into humans by e.g. B1religiousB2 surroundings in which they live (taken from other	ihmiset omaksuvat A1sodanA2 hyväksynnän mm. elinympäristön B1uskonnostaB2

		part of article)	
Water	Biology	from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life (taken from other part of article)	B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiselle
Water	Human	storage of A1waterA2 is important, since it is essential to B1humanB2 life (taken from other part of article)	A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle
Water	Organism	existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2 (taken from other part of article)	A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2
Water	Oxygen	components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe (taken from other part of article)	A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa
Water	Plant	there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2 (taken from other part of article)	A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta
Water	Sea	liquid A1waterA2 is found in bodies of water such as B1seaB2 (taken from other part of article)	nestemäistä A1vettäA2 esintyy vesistöissä, kuten B1meressäB2
Water	Sun	the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2 (taken from other part of article)	maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa
Water	Travel	concerning A1waterA2 rivers and seas offer opportunity for B1travelB2 (taken from other part of article)	A1veteenA2 liittyen joet ja meret tarjoavat tilaisuuden B1matkustamiselleB2

Additional hyperlinks for rolling back

14 hyperlinks in addition to 212 above mentioned hyperlinks that were traversed to roll back to previously visited concept when the student's exploration had lead to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration:

<i>Hyperlink</i>	<i>Number of traversals</i>
Disease->Oxygen	1
Experience->Emotion	18
Experience->Learning	8
Happiness->Love	4
Heart->Organism	6
Heart->Death	5
Joy->Emotion	7
Learning->Teacher	3
Television->Adolescence	3
Television->Clothing	1
Television->Light	1
Television->Leisure	1
Travel->Water	3
Work->Leisure	5

Appendix K

Listing of the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), shown for all students and also separately for male students (n=18) and female students (n=31). Exploration experiment with students was carried out in “hyperlink network of 55 concepts” containing 212 hyperlinks connecting 55 concepts. All 212 hyperlinks of “hyperlink network of 55 concepts” are connecting concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (containing 55 concepts including concept Human). This listing shows the number of traversals for those hyperlinks of 212 hyperlinks that became traversed by students and as well as for additional roll back hyperlinks (shown in Appendix J). Please note that in exploration experiment each student was allowed to traverse each hyperlink belonging to “hyperlink network of 55 concepts” at most once (except in case of roll back hyperlinks).

This listing also shows for all students the number of selectable alternative hyperlinks (average) shown to the student when she selected to traverse a hyperlink that was just before traversing current hyperlink. The number of traversals for hyperlinks departing from Human includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis is shown the number of traversals when excluding hyperlinks departing from concept Human that were the student’s first traversed hyperlink in exploration path. Indicated with an asterisk (*), for hyperlinks departing from concept Human the number of selectable alternative hyperlinks (average) is calculated only based on those traversals of hyperlinks departing from concept Human that were not the student’s first traversed hyperlink in her exploration path. Among 16 alternative hyperlinks departing from concept Human there did not occur any traversals for hyperlinks Human->God and Human->Old_age.

<i>All students participating in exploration task (n = 49)</i>			<i>All male students participating in exploration task (n = 18)</i>		<i>All female students participating in exploration task (n = 31)</i>	
<i>Traversed hyperlink (current hyperlink)</i>	<i>Number of traversals</i>	<i>Number of selectable alternative hyperlinks (average) shown to student when she selected to traverse a <u>hyperlink that was just before</u> traversing current hyperlink</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>
Happiness -> Emotion	29	3.758621	Animal -> Nature	4	Happiness -> Emotion	25
Emotion -> Love	26	1.846154	Joy -> Happiness	4	Emotion -> Love	23
Joy -> Happiness	24	2.125	Happiness -> Joy	4	Disease -> Death	22
Disease -> Death	24	4.625	Happiness -> Emotion	4	Joy -> Happiness	20
Happiness -> Joy	21	4.285714	Sun -> Oxygen	3	Adolescence -> Education	17
Human -> Diet_(nutrition)	19 (2*)	5.5*	Sun -> Plant	3	Happiness -> Joy	17
Emotion -> Experience	19	7.263158	Biology -> Animal	3	Human -> Diet_(nutrition)	16
Experience -> Emotion (only to roll back)	18	3.833333	Organism -> Biology	3	Emotion -> Experience	16
Organism -> Biology	17	5.176471	Organism -> Plant	3	Experience -> Emotion (only to roll back)	15
Adolescence ->	17	6.764706	Organism -> Heart	3	Organism ->	14

Education						Biology	
Love -> Friendship	16	2.75		Oxygen -> Sun	3	Education -> Learning	14
Education -> Learning	14	3.428571		Oxygen -> Plant	3	Learning -> Education	14
Learning -> Education	14	5.642857		Oxygen -> Water	3	Love -> Friendship	14
Emotion -> Happiness	14	3.571429		Human -> Diet_(nutrition)	3	Family -> Mother	12
Family -> Mother	13	8.384615		Plant -> Nature	3	Health -> Disease	12
Diet_(nutrition) -> Health	13	14.92308		Plant -> Tree	3	Diet_(nutrition) -> Health	11
Health -> Disease	13	10.38462		Experience -> Emotion (only to roll back)	3	Emotion -> Happiness	11
Love -> Happiness	11	6.363636		Happiness -> Love (only to roll back)	3	Emotion -> Joy	10
Emotion -> Joy	11	2.090909		Love -> Happiness	3	Friendship -> Adolescence	10
Love -> Emotion	10	5.4		Emotion -> Experience	3	Biology -> Nature	9
Friendship -> Adolescence	10	5.3		Emotion -> Happiness	3	Human -> Adolescence	9
Biology -> Nature	9	3.444444		Emotion -> Love	3	Adolescence -> Child	9
Organism -> Plant	9	4.888889		Automobile -> Oxygen	2	Love -> Emotion	9
Oxygen -> Water	9	6.333333		Animal -> Organism	2	Human -> Family	8
Human -> Adolescence	9 (2*)	7*		Oxygen -> Automobile	2	Human -> Emotion	8
Human -> Family	9 (6*)	7.333333*		Death -> Organism	2	Experience -> Learning (only to roll back)	8
Human -> Emotion	9 (3*)	6		Nature -> Animal	2	Death -> Disease	8
Adolescence -> Child	9	9.555556		Nature -> Human	2	Death -> War	8
Sun -> Plant	8	5.375		Travel -> Water	2	Learning -> Experience	8
Organism -> Heart	8	5.875		Family -> Father	2	Love -> Happiness	8
Human -> Health	8 (3*)	6.666667*		Tree -> Oxygen	2	War -> Peace	8
Experience -> Learning (only to roll back)	8	1.75		Love -> Biology	2	Biology -> Organism	7
Death -> Disease	8	1.75		Love -> Friendship	2	Human -> Health	7
Death -> War	8	1.75		Diet_(nutrition) -> Organism	2	Family -> Sibling	7
Learning -> Experience	8	7.375		Diet_(nutrition) -> Health	2	Love -> Family	7
Love -> Family	8	3.5		Disease -> Death	2	Organism -> Plant	6
War -> Peace	8	8.5		Sibling -> Love	2	Animal -> Human	6
Mother -> Parent	8	4.5		Heart -> Organism	2	Oxygen -> Water	6
Biology -> Organism	7	5.857143		Health -> Diet_(nutrition)	2	Joy -> Emotion (only to roll back)	6
Biology -> Animal	7	4.142857		Parent -> Sibling	2	School -> Education	6
Oxygen -> Plant	7	6		Water -> Oxygen	2	Education -> School	6
Joy -> Emotion (only to roll back)	7	1.142857		Water -> Travel	2	Education -> Adolescence	6
Plant -> Tree	7	2.571429		Friendship -> Animal	2	Education -> Leisure	6
Sea -> Water	7	7.857143		Mother -> Parent	2	Death -> Human	6
Family -> Sibling	7	9.428571		Biology -> Human	1	Child -> Family	6
Sibling -> Love	7	5.571429		Biology -> Plant	1	Sea -> Water	6
Water -> Sea	7	6.428571		Animal -> Oxygen	1	Teacher -> Learning	6
Sun -> Oxygen	6	3.5		Animal -> Water	1	Family -> Child	6
Animal -> Human	6	5.666667		Oxygen -> Disease	1	Peace -> Education	6
Animal -> Nature	6	7.333333		Human -> Oxygen	1	Water -> Sea	6
Human -> Happiness	6 (5*)	6.6*		Human -> Happiness	1	Mother -> Parent	6
Plant -> Nature	6	4.333333		Human -> Family	1	Sun -> Plant	5
Plant -> Light	6	3.5		Human -> War	1	Organism -> Heart	5
School ->	6	3.5		Human -> Health	1	Human ->	5

Education						Happiness	
Education -> School	6	2.833333		Human -> Emotion	1	Plant -> Light	5
Education -> Adolescence	6	2		Human -> Religion	1	Education -> Human	5
Education -> Leisure	6	1.833333		Joy -> Emotion (only to roll back)	1	Education -> Teacher	5
Death -> Organism	6	1		Father -> Family	1	Child -> Adolescence	5
Death -> Human	6	1.333333		Father -> Sibling	1	Teacher -> School	5
Child -> Family	6	3.333333		Father -> Mother	1	Sibling -> Love	5
Teacher -> Learning	6	5.5		God -> Father	1	Health -> Biology	5
Family -> Child	6	6.5		Plant -> Biology	1	Work -> Leisure (only to roll back)	5
Peace -> Education	6	3		Plant -> Animal	1	Parent -> Human	5
Diet_(nutrition) -> Organism	6	13.83333		Plant -> Light	1	Parent -> Birth	5
Heart -> Organism (only to roll back)	6	2.333333		Plant -> Water	1	Leisure -> Work	5
Mother -> Love	6	4.833333		Death -> Heart	1	Mother -> Love	5
Biology -> Human	5	4.8		Nature -> Sun	1	Biology -> Animal	4
Human -> War	5 (3*)	5.666667*		Nature -> Organism	1	Biology -> Human	4
God -> Father	5	3		Nature -> Oxygen	1	Oxygen -> Plant	4
Education -> Human	5	2.2		Sea -> Water	1	Human -> War	4
Education -> Teacher	5	2.4		Family -> Mother	1	Father -> Love	4
Death -> Heart	5	1.6		Tree -> Water	1	God -> Father	4
Child -> Adolescence	5	5.2		Love -> Family	1	Plant -> Tree	4
Teacher -> School	5	4.2		Love -> Emotion	1	School -> Teacher	4
Tree -> Oxygen	5	7.4		Diet_(nutrition) -> Religion	1	Death -> Organism	4
Love -> Biology	5	1.6		Disease -> Oxygen (only to roll back)	1	Death -> Heart	4
Heart -> Death (only to roll back)	5	6.6		Sibling -> Parent	1	Child -> Parent	4
Health -> Biology	5	4		War -> Disease	1	Adolescence -> Old_age	4
Work -> Leisure (only to roll back)	5	4.8		Heart -> Death (only to roll back)	1	Family -> Leisure	4
Religion -> God	5	2.4		Health -> Disease	1	Diet_(nutrition) -> Organism	4
Light -> Sun	5	6.2		Emotion -> Joy	1	War -> Religion	4
Parent -> Human	5	6		Religion -> Sun	1	Heart -> Organism	4
Parent -> Birth	5	6.4		Religion -> God	1	Heart -> Death (only to roll back)	4
Leisure -> Work	5	5.2		Light -> Sun	1	Religion -> God	4
Animal -> Organism	4	4.25		Parent -> Mother	1	Light -> Sun	4
Father -> Love	4	4.75		Water -> Sun	1	Leisure -> Family	4
School -> Teacher	4	9.5		Water -> Human	1	Sun -> Oxygen	3
Child -> Parent	4	4.25		Water -> Plant	1	Human -> Love	3
Nature -> Animal	4	6.5		Water -> Sea	1	Human -> Clothing	3
Nature -> Human	4	6.25		Mother -> Love	1	Plant -> Organism	3
Adolescence -> Old_age	4	9.25				Plant -> Nature	3
Happiness -> Love	4	3				Nature -> Plant	3
Family -> Father	4	5.75				Adolescence -> Television	3
Family -> Leisure	4	7.75				Learning -> Teacher (only to roll back)	3
War -> Religion	4	6.75				Tree -> Oxygen	3
Health -> Diet_(nutrition)	4	7.5				Love -> Biology	3
Leisure -> Family	4	5.25				Diet_(nutrition) -> Death	3
Water -> Sun	4	2.75				Birth -> Animal	3
Oxygen -> Sun	3	5				Television -> Adolescence (only to roll back)	3

Oxygen -> Disease	3	1.333333			Religion -> Human	3
Human -> Love	3 (2*)	7.5*			Old_age -> Death	3
Human -> Religion	3 (0*)	not available since no other hyperlinks were traversed before traversing Human -> Religion*			Water -> Sun	3
Human -> Clothing	3 (2*)	6*			Biology -> Health	2
Father -> Family	3	3.666667			Animal -> Organism	2
Plant -> Organism	3	3			Animal -> Nature	2
Plant -> Water	3	3.333333			Oxygen -> Disease	2
Nature -> Sun	3	6			Oxygen -> Heart	2
Nature -> Organism	3	6.333333			Human -> House	2
Nature -> Oxygen	3	6.666667			Human -> Religion	2
Nature -> Plant	3	6.333333			Father -> Family	2
Travel -> Water	3	7			Father -> Parent	2
Adolescence -> Television	3	7.333333			Plant -> Oxygen	2
Learning -> Teacher (only to roll back)	3	1.666667			Plant -> Water	2
Diet_(nutrition) -> Death	3	12			Home -> Family	2
Sibling -> Parent	3	3.666667			Education -> Biology	2
War -> Disease	3	12.333333			Death -> Oxygen	2
Birth -> Animal	3	6			Nature -> Sun	2
Television -> Adolescence (only to roll back)	3	3.333333			Nature -> Organism	2
Religion -> Human	3	11.333333			Nature -> Animal	2
Old_age -> Death	3	4.333333			Nature -> Oxygen	2
Water -> Oxygen	3	3.333333			Nature -> Human	2
Water -> Plant	3	1			Family -> Father	2
Water -> Travel	3	2			Peace -> War	2
Automobile -> Oxygen	2	6			Sibling -> Family	2
Biology -> Plant	2	2.5			Sibling -> Parent	2
Biology -> Health	2	3			War -> Disease	2
Oxygen -> Automobile	2	2			House -> Home	2
Oxygen -> Heart	2	3.5			Health -> Diet_(nutrition)	2
Human -> Oxygen	2 (1*)	7*			Clothing -> Religion	2
Human -> House	2 (1*)	3*			Light -> Television	2
Father -> Parent	2	5			Parent -> Father	2
Father -> Mother	2	4.5			Parent -> Child	2
Plant -> Biology	2	6			Leisure -> Education	2
Plant -> Animal	2	5			Leisure -> Sibling	2
Plant -> Oxygen	2	7			Water -> Biology	2
Home -> Family	2	4			Water -> Plant	2
Education -> Biology	2	3			Friendship -> Love	2
Death -> Oxygen	2	2.5			Mother -> Father	2
Tree -> Water	2	6			Biology -> Plant	1
Peace -> War	2	3			Human -> Animal	1
Sibling -> Family	2	4.5			Human -> Oxygen	1
House -> Home	2	15.5			Human -> Music	1
Religion -> Sun	2	9			Father -> Mother	1
Clothing -> Religion	2	8.5			Plant -> Biology	1
Light -> Television	2	8			Plant -> Animal	1
Parent -> Father	2	7			Education -> Sibling	1
Parent -> Child	2	5			Child -> Old_age	1
Parent -> Sibling	2	6			Child -> Leisure	1
Leisure ->	2	1			Travel -> Water	1

Education							
Leisure -> Sibling	2	6				Happiness -> Love (only to roll back)	1
Water -> Biology	2	3.5				Teacher -> Education	1
Friendship -> Animal	2	5.5				Tree -> Water	1
Friendship -> Love	2	5.5				Food -> Human	1
Mother -> Father	2	5				Birth -> Death	1
Animal -> Oxygen	1	7				Birth -> Mother	1
Animal -> Water	1	7				Television -> Clothing (only to roll back)	1
Human -> Animal	1 (0*)	not available since no other hyperlinks were traversed before traversing Human -> Animal*				Television -> Light (only to roll back)	1
Human -> Music	1 (1*)	9*				Television -> Leisure (only to roll back)	1
Father -> Sibling	1	5				Health -> Food	1
Education -> Sibling	1	2				Religion -> Sun	1
Child -> Old_age	1	4				Clothing -> Television	1
Child -> Leisure	1	5				Old_age -> Adolescence	1
Teacher -> Education	1	2				Leisure -> Television	1
Diet_(nutrition) -> Religion	1	4				Water -> Oxygen	1
Food -> Human	1	3				Water -> Travel	1
Disease -> Oxygen (only to roll back)	1	5				Mother -> Family	1
Birth -> Death	1	6					
Birth -> Mother	1	6					
Television -> Clothing (only to roll back)	1	2					
Television -> Light (only to roll back)	1	2					
Television -> Leisure (only to roll back)	1	5					
Health -> Food	1	4					
Clothing -> Television	1	15					
Parent -> Mother	1	7					
Old_age -> Adolescence	1	4					
Leisure -> Television	1	10					
Water -> Human	1	6					
Mother -> Family	1	3					

Appendix L

Based on Appendix K we have identified the most actively traversed departing and arriving hyperlinks for each of 55 concepts in “hyperlink network of 55 concepts” during exploration experiment with students (n=49). For arriving hyperlinks we express the number of unique end concepts that have got traversed arrivals during surfing per unique end concepts that could have got traversed arrivals in “hyperlink network of 55 concepts” for observed concept, and we also express the end concept for most actively traversed hyperlink departing from observed concept. For departing hyperlinks we express the number of unique start concepts that have got traversed departures during surfing per unique start concepts that could have got traversed departures in “hyperlink network of 55 concepts” for observed concept, and we also express the start concept for most actively traversed hyperlink arriving to observed concept.

If several hyperlinks of observed concept share the position as the most actively traversed departing hyperlink or the most actively traversed arriving hyperlink all corresponding end concepts or start concepts are listed in the table (for example both hyperlinks Animal->Human and Animal->Nature depart from concept Animal and both links Animal->Human and Death->Human arrive at concept Human). For some observed concepts some of traversed departing or arriving hyperlinks are traversals of rolling back and in these cases the values and concepts (if there are any) are listed also without traversals of rolling back, and also hyperlinks traversed for rolling back are listed.

Observed concept	Arriving hyperlinks of “hyperlink network of 55 concepts”		Departing links of “hyperlink network of 55 concepts”	
<i>Concept among 55 concepts of “hyperlink network of 55 concepts”</i>	<i>The number of unique end concepts that have got traversed arrivals during surfing per number of unique end concepts that could have got traversed arrivals in “hyperlink network of 55 concepts” for observed concept</i>	<i>End concept for most actively traversed hyperlink departing from observed concept (N/A = not available)</i>	<i>The number of unique start concepts that have got traversed departures during surfing per number of unique start concepts that could have got traversed departures in “hyperlink network of 55 concepts” for observed concept</i>	<i>Start concept for most actively traversed hyperlink arriving to observed concept (N/A = not available)</i>
Adolescence	4per4	Education	6per6 (without traversals of rolling back 5per6 (rolling back television->adolescence))	Friendship
Animal	5per7	Human; Nature	6per8	Biology
Automobile	1per1	Oxygen	1per1	Oxygen
Biology	6per6	Nature	6per9	Organism
Birth	3per4	Animal	1per1	Parent
Cat	0per3	N/A	0per2	N/A
Child	5per6	Family	3per5	Adolescence
Clothing	2per2	Religion	2per1 (without traversals of rolling back 1per1 (rolling back television->clothing))	Human
Computer	0per2	N/A	0per1	N/A
Death	6per7	Disease; War	5per5 (without traversals of rolling back 4per5 (rolling back heart->death))	Disease
Diet_(nutrition)	4per4	Health	2per4	Human
Disease	2per1 (without traversals of rolling back 1per1 (rolling back disease->oxygen))	Death	4per4	Health
Dog	0per3	N/A	0per2	N/A
Education	8per10	Learning	6per6	Adolescence
Emotion	4per4	Love	5per3 (without traversals of rolling back 3per3 (rolling back experience->emotion; joy->emotion))	Happiness
Experience	2per0 (without traversals of rolling back 0per0 (rolling	Emotion (without traversals of rolling	2per2	Emotion

	back experience->learning; experience->emotion))	back N/A)		
Family	5per5	Mother	8per10	Human
Father	5per5	Love	4per5	God
Food	1per10	Human	1per1	Health
Friendship	3per3	Adolescence	1per1	Love
God	1per3	Father	1per2	Religion
Happiness	3per2 (without traversals of rolling back 2per2 (rolling back happiness->love))	Emotion	4per4	Joy
Health	4per4	Disease	3per4	Diet_(nutrition)
Heart	2per0 (without traversals of rolling back 0per0 (rolling back heart->organism; heart- >death))	Organism (without traversals of rolling back N/A)	3per3	Organism
Home	1per3	Family	1per1	House
House	1per4	Home	1per2	Human
Human	14per16	Diet_(nutrition)	9per11	Animal; Death
Joy	2per1 (without traversals of rolling back 1per1 (rolling back joy->emotion))	Happiness	2per2	Happiness
Learning	3per2 (without traversals of rolling back 2per2 (rolling back learning->teacher))	Education	3per2 (without traversals of rolling back 2per2 (rolling back experience- >learning))	Education
Leisure	5per5	Work	5per4 (without traversals of rolling back 3per4 (rolling back television- >leisure; work->leisure))	Education
Light	2per2	Sun	2per1 (without traversals of rolling back 1per1 (rolling back television- >light))	Plant
Love	5per6	Friendship	7per7 (without traversals of rolling back 6per7 (rolling back happiness- >love))	Emotion
Mother	4per7	Parent	4per5	Family
Music	0per2	N/A	1per1	Human
Nature	6per7	Animal; Human	3per4	Biology
Old_age	2per4	Death	2per3	Adolescence
Organism	3per3	Biology	7per7 (without traversals of rolling back 6per7 (rolling back heart- >organism))	Biology
Oxygen	6per6	Water	10per9 (without traversals of rolling back 9per9 (rolling back disease->oxygen))	Sun
Parent	6per6	Human; Birth	4per4	Mother
Peace	2per2	Education	1per1	War
Pet	0per3	N/A	0per3	N/A
Plant	8per8	Tree	6per8	Organism
Religion	3per3	God	4per7	War
School	2per2	Education	2per3	Education
Sea	1per1	Water	1per1	Water
Sibling	3per5	Love	5per7	Family
Sun	2per2	Plant	5per6	Light
Teacher	3per3	Learning	3per2 (without traversals of rolling back 2per2 (rolling back learning- >teacher))	Education
Telephone	0per0	N/A	0per1	N/A
Television	4per0 (without traversals of rolling back 0per0 (rolling back television- >adolescence; television- >clothing; television->light; television->leisure))	Adolescence (without traversals of rolling back N/A)	4per7	Adolescence
Travel	1per0 (without traversals of rolling back 0per0 (rolling back travel->water))	Water (without traversals of rolling back N/A)	1per1	Water
Tree	2per2	Oxygen	1per1	Plant
War	3per3	Peace	3per4	Death
Water	7per8	Sea	6per6 (without traversals of rolling back 5per6 (rolling back travel-	Oxygen

			>water))	
Work	1per0 (without traversals of rolling back 0per0 (rolling back work->leisure))	Leisure (without traversals of rolling back N/A)	1per1	Leisure

Appendix M

User interface of a prototype tool used by 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming” (texts provided only in Finnish), as discussed in Subchapter 8.2.

Concept map tool. (c) Lauri.Lahti@tkk.fi

Piirrä käsitekartta, joka kuvaavaa aihetta "ohjelmointi". Tyyli on vapaa ja aikaa 15 minuuttia.

KÄSITTEET: Lisää käsitteitä kirjoittamalla ilmaisu tekstikenttään ja painamalla "Uusi käsite".

NUOLET: Lisää käsitteiden välille selityksillä varustettuja nuolia.

Valitse **lähtökäsite** (sininen) hiiren vasemmalla painikkeella ja **kohdekäsite** (punainen) hiiren oikealla painikkeella. Kirjoita suhdetta kuvaava ilmaisu tekstikenttään ja paina "Uusi nuoli". (Voit korvata hiiren oikean painikkeen yhdistelmällä Control/Ctrl-näppäin ja hiiren vasen painike.)

Rakenna käsitekartta, joka esittelee 10-20 tärkeintä käsitettä liittyen ohjelmointiin ja niiden väliset tärkeimmät suhteet. Tarvittaessa voit uudelleennimetä tai poistaa käsitteitä ja nuolia, sekä siirtää niitä raahaamalla. Alla on eräs esimerkki mahdollisesta käsitekartan rakenteesta. Luota rohkeasti omaan näkemykseesi, piirrä nopeasti ja paljon, suurpiirteisyys ei häiritse.

Teksti käsitteelle/nuolelle:

Uusi käsite **Uudelleen-nimeä käsite** **Poista käsite**

Uusi nuoli **Uudelleen-nimeä nuoli** **Poista nuoli**

Taustatietoja opiskelijasta:

Opiskelijanumero: Ikä: Valitse: Sukupuoli: Valitse:

Paljonko sinulla on kokemusta ohjelmoinnista ennen ohjelmointikurssia? Valitse:

Onko sinulle tällä hetkellä helppoa oppia ohjelmointia? Valitse:

Anna arvio, kuinka monimutkaisia asioita käsitekarttasi käsittelee. Valitse:

Tallentaminen (paina kun saat työsi valmiiksi) **Aikaa jäljellä 15 min.**

```
graph TD
    Mysi[Mysi] -- "seos jossa mm. ruunoita" --> Vilja[Vilja]
    Vilja -- "kasvupaikkana" --> Pelto[Pelto]
    Vilja -- "jyvien jauhaminen esim. myllyssä" --> Jauhot[Jauhot]
    Jauhot -- "perinteisesti vehnäväst" --> Patonki[Patonki]
    Jauhot -- "sekoitetaan taikinaksi ja paistetaan" --> Leipomotuotteet[Leipomotuotteet]
    Jauhot -- "asim. ruista tai vehnää" --> Leipä[Leipä]
    Leipä -- "suolainen" --> Leipomotuotteet
    Leipä -- "vipale, joka on vortseitu" --> Voileipä[Voileipä]
    Leipä -- "Ranskassa tavallinen" --> Patonki
    Leipä -- "makea" --> KakutLeivokset[Kakut ja leivokset]
    Voileipä -- "terveellisempi vaihtoa" --> KakutLeivokset
    Hiiva[Hiiva] -- "auttaa kohoamaan" --> Leipomotuotteet
```

Responses of 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming”. After eliminating unclear responses and transforming all concepts to non-conjugated base forms, there were 167 unique concepts and 167 unique conceptual relationships between them mentioned by at least two students. Both a listing of these unique concepts and a listing of these unique conceptual relationships are shown in table below showing number of occurrences in all 147 concept maps.

<i>Concept</i>	<i>Occurrences (at most one occurrence counted for each student)</i>		<i>Conceptual relationship</i>	<i>Occurrences (at most one occurrence counted for each student)</i>
programming	90		object -> method	29
object	62		class -> object	27
method	60		programming -> programming language	27
java	57		programming language -> java	18
class	49		programming -> language	17
program	47		class -> method	14
programming language	44		java -> object	14
variable	41		programming -> program	14
python	31		object -> variable	12
c	29		language -> java	11
programmer	25		language -> c	10
language	24		program -> class	10
object-oriented programming	22		object -> class	9
computer	21		variable -> object	9
user	21	user	java -> object-oriented programming	8
compiler	20		language -> python	8
c++	19		programming language -> c	8
code	17		programming -> object	8
user interface	16		programming -> object-oriented programming	8
loop	13		programming language -> python	7
debugger	12		class -> variable	6
eclipse	12		method -> object	6
problem	11		object-oriented programming -> java	6
algorithm	9		programming -> computer	6
conditional sentence	9		programming -> java	6
int	9		programming -> tool	6
parameter	9		c -> c++	5
program code	9		code -> program	5
ready program	9		java -> class	5
starting method	9		method -> class	5
tool	9		method -> variable	5
library	8		package -> class	5
machine language	8		programmer -> program	5
testing	8		programmer -> programming	5
constructor	7		programmer -> programming language	5
list	7		programming -> programmer	5
string	7		programming -> user interface	5
double	6		programming -> variable	5
function	6		variable -> method	5
gui	6		class -> constructor	4
operating system	6		code -> compiler	4
planning	6		java -> variable	4
assembly	5		object-oriented programming -> object	4
bug	5		program -> user	4
debugging	5		programming language -> c++	4
grafical user interface	5		programming -> code	4
hardware	5		programming -> python	4
instance variable	5		user -> program	4
package	5		c -> language	3
php	5		java -> language	3
prosessor	5		java -> method	3
application generator	4		language -> assembly	3
boolean	4		language -> paradigm	3

command	4		loop -> for	3
editor	4		loop -> while	3
information structure	4		method -> value	3
internet	4		object -> list	3
javascript	4		object-oriented programming -> class	3
lecture	4		object-oriented programming -> python	3
mathematics	4		problem -> programming	3
memory	4		program code -> object	3
paradigm	4		program -> code	3
primitive type	4		program -> library	3
primitive variable	4		program -> object	3
programming environment	4		program -> operating system	3
source code	4		program -> user interface	3
syntax	4		programmer -> code	3
value	4		programming language -> code	3
abstraction level	3		programming language -> machine language	3
aim	3		programming language -> object-oriented programming	3
application	3		programming -> assistive tool	3
application program	3		programming -> user	3
assistive tool	3		python -> language	3
basic	3		python -> object	3
char	3		tool -> compiler	3
client	3		tool -> debugger	3
coding	3		user -> code	3
concept	3		variable -> instance	3
for	3		variable -> local	3
functional programming	3		abstraction level -> high	2
functioning of program	3		abstraction level -> low	2
functioning program	3		assistive tool -> debugger	2
human	3		assistive tool -> eclipse	2
if	3		c++ -> language	2
instance	3		c++ -> object-oriented programming	2
keeper of the most recent	3		c++ -> program	2
local	3		class -> program code	2
logic	3		code -> programming language	2
parsing	3		compiler -> machine language	2
plan	3		computer -> code	2
structure	3		computer -> program	2
task	3		computer -> programming	2
while	3		eclipse -> debugger	2
virtual machine	3		editor -> code	2
visual basic	3		information -> variable	2
agile	2		input -> method	2
artificial intelligence	2		java -> concept	2
asm	2		java -> eclipse	2
basic data type	2		java -> loop	2
book	2		java -> program	2
c language	2		language -> c++	2
c#	2		library -> class	2
c/c++	2		loop -> do	2
clarity	2		loop -> programming	2
coder	2		memory -> processor	2
computation	2		method -> output	2
computer program	2		method -> parameter	2
constructor parameter	2		object -> algorithm	2
database	2		object -> object	2
development	2		object -> parameter	2
do	2		object -> programming	2
documentation	2		object-oriented programming -> variable	2
else	2		parameter -> method	2
environment	2		plan -> program code	2
example	2		primitive type -> boolean	2
for example java	2		problem -> program	2
function programming	2		problem -> programming language	2
function-based	2		program code -> class	2
google	2		program code -> variable	2
grafical	2		program -> application	2

hardware level	2		program -> bug	2
high	2		program -> compiler	2
history	2		program -> function	2
i	2		program -> hardware	2
ide	2		program -> method	2
information	2		program -> other programmer	2
information processing	2		program -> tool	2
input	2		program -> variable	2
integer	2		programmer -> user	2
java programming	2		programming environment -> eclipse	2
keeper of the most suitable	2		programming language -> php	2
local variable	2		programming language -> programming	2
logic operator	2		programming -> abstraction level	2
logic thinking	2		programming -> algorithm	2
loosing attention	2		programming -> c	2
low	2		programming -> c++	2
machine	2		programming -> class	2
not working	2		programming -> compiler	2
object-based	2		programming -> computer program	2
other	2		programming -> function	2
other language	2		programming -> information structure	2
other object	2		programming -> logic	2
other programmer	2		programming -> machine language	2
output	2		programming -> mathematics	2
pascal	2		programming -> method	2
private	2		programming -> other language	2
problem/task	2		programming -> program code	2
procedural programming	2		programming -> programming environment	2
public	2		programming -> style	2
result	2		programming -> theory	2
returning of value	2		processor -> program	2
role	2		starting method -> class	2
scheme	2		structure -> conditional sentence	2
software	2		testing -> programming	2
solution	2		tool -> application generator	2
studying	2		user interface -> grafical	2
style	2		user interface -> program	2
syntax error	2		user interface -> text-based	2
table	2		user interface -> user	2
text-based	2		user -> programmer	2
theory	2		variable -> class	2
type	2		variable -> double	2
utility program	2		variable -> instance variable	2
waterfall	2		variable -> int	2
web	2		variable -> keeper of the most recent	2
void	2		variable -> keeper of the most suitable	2
working life	2		variable -> parameter	2

This is a listing of response alternatives for self-evaluation of 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming” (analysis of responses given by students is discussed in Subchapter 8.2)

For three questions the student replied by selecting a most suitable answer from a scale of five given alternatives that are listed here next.

Response alternatives for question “How much you have experience about programming before participating introductory programming course?”:

Very much; Much; Moderately; Little; or Very little.

(In Finnish: Paljonko sinulla on kokemusta ohjelmoinnista ennen ohjelmontikurssi?
Erittäin paljon; Paljon; Kohtalaisesti; Vähän; tai Erittäin vähän.)

Response alternatives for question “Is it easy for you at the moment to learn programming?”:
Very easy; Easy; Moderate; Difficult; or Very difficult.

(In Finnish: Onko sinulle tällä hetkellä helppoa oppia ohjelmointia?
Erittäin helppoa; Helppoa; Kohtalaista; Vaikeaa; tai Erittäin vaikeaa.)

Response alternatives for question “Please give an estimate about how complex things your concept map is dealing with?”:

Very complex; Complex; Moderate; Simple; or Very simple.

(In Finnish: Anna arvio, kuinka monimutkaisia asioita käsittekarttasi käsittelee.

Erittäin monimutkaisia; Monimutkaisia; Kohtalaisia; Yksinkertaisia; tai Erittäin yksinkertaisia.)

Appendix N

This listing is based on listings of Table 3.9 and Appendix K to enable comparing the highest-ranking core relationships in concept maps drawn by students (n=103) and traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), and to identify those relationships that exist in both listings, indicated with an asterisk (*).

In columns 1-3 is a list of 145 core relationships that are in fact all those relationships between 102 core concepts extended with concept “brother” that are mentioned by at least two students in concept maps drawn by students (n=103), shown in descending order of occurrences in concept maps (based on Table 3.9). However to enable comparison with knowledge structures of the Wikipedia, each concept was transformed to the closest matching entry of Wikipedia articles according to listing of Appendix F which also explains why Sibling is used to represent concept “brother”. Since relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order.

In columns 4-6 is a list of highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), shown for all students (based on Appendix K). Exploration experiment with students was carried out in “hyperlink network of 55 concepts” containing 212 hyperlinks connecting 55 concepts. The number of traversals for hyperlinks departing from Human (for example for Human -> Diet_(nutrition) value 19) includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis (for example for Human -> Diet_(nutrition) value 2) is shown the number of traversals when excluding hyperlinks departing from concept Human that were the student’s first traversed hyperlink in exploration path.

Hyperlinks supplied with notation “only to roll back” belong to 14 hyperlinks (shown in Appendix J) that supplement 212 hyperlinks of “hyperlink network of 55 concepts” and were traversed to roll back to previously visited concept when the student’s exploration had lead to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration.

In contrast with practice used often elsewhere in this publication, in Appendix N as well as in Table 9.1 and Table 9.2 if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is a ranking value that would have been used next if there were not need for sharing the position (i.e. we now avoid using an average of all ranking values that would have been used if there were not need for sharing the position and skipping corresponding number of ranking values). We decided to use all ranking values even in case of shared ranking so that our analysis about overlap of listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks discussed in Chapter 9 could become more intuitive.

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Core relationships (i.e. relationships between 102 core concepts extended with concept "brother" that are mentioned by at least two students in concept maps drawn by students) shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order) (n=103)</i>	<i>Number of occurrences so that at most one occurrence counted for each student</i>	<i>Ranking</i>	<i>Traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>	<i>Number of occurrences so that at most one occurrence counted for each student</i>	<i>Ranking</i>
Family↔Friendship	15	1	Happiness -> Emotion	29	1
* Birth↔Death	13	2s	* Emotion -> Love	26	2
* Family↔Love	13	2s	Joy -> Happiness	24	3s
Friendship↔School	10	3	* Disease -> Death	24	3s
* Family↔Home	9	4s	Happiness -> Joy	21	4
School↔Work	9	4s	Human -> Diet_(nutrition)	19 (2)	5s
* Animal↔Nature	8	5s	Emotion -> Experience	19	5s
* Friendship↔Love	8	5s	Experience -> Emotion (only to roll back)	18	6
* Child↔Family	7	6s	Organism -> Biology	17	7s
Death↔Living	7	6s	Adolescence -> Education	17	7s
* Family↔Father	7	6s	* Love -> Friendship	16	8
Family↔Living	7	6s	Education -> Learning	14	9s
Joy↔Sorrow	7	6s	Learning -> Education	14	9s
* Family↔Mother	6	7s	Emotion -> Happiness	14	9s
* Father↔Mother	6	7s	* Family -> Mother	13	10s
Food↔Water	6	7s	Diet_(nutrition) -> Health	13	10s
Friendship↔Hobby	6	7s	* Health -> Disease	13	10s
Money↔Work	6	7s	* Love -> Happiness	11	11s
Birth↔Living	5	8s	Emotion -> Joy	11	11s
Education↔Work	5	8s	* Love -> Emotion	10	12s
Living↔Nature	5	8s	* Friendship -> Adolescence	10	12s
* Nature↔Plant	5	8s	* Biology -> Nature	9	13s
* Plant↔Tree	5	8s	Organism -> Plant	9	13s
Study↔Work	5	8s	* Oxygen -> Water	9	13s
Animal↔Dog	4	9s	Human -> Adolescence	9 (2)	13s
Atmosphere_of_Earth↔Water	4	9s	* Human -> Family	9 (6)	13s
Cat↔Dog	4	9s	Human -> Emotion	9 (3)	13s
Computer↔Television	4	9s	Adolescence -> Child	9	13s
* Death↔Disease	4	9s	Sun -> Plant	8	14s
Death↔Health	4	9s	Organism -> Heart	8	14s
Family↔Happiness	4	9s	Human -> Health	8 (3)	14s
* Family↔Human	4	9s	Experience -> Learning (only to roll back)	8	14s
Friendship↔Happiness	4	9s	* Death -> Disease	8	14s
Friendship↔Human	4	9s	* Death -> War	8	14s
Friendship↔Joy	4	9s	Learning -> Experience	8	14s
Home↔Living	4	9s	* Love -> Family	8	14s
Human↔Living	4	9s	War -> Peace	8	14s
* Human↔Love	4	9s	Mother -> Parent	8	14s
* Human↔Nature	4	9s	Biology -> Organism	7	15s
Living↔Work	4	9s	Biology -> Animal	7	15s
Nature↔Water	4	9s	Oxygen -> Plant	7	15s
Animal↔Family	3	10s	Joy -> Emotion (only to roll back)	7	15s
Animal↔Food	3	10s	* Plant -> Tree	7	15s
* Animal↔Human	3	10s	* Sea -> Water	7	15s
* Biology↔Nature	3	10s	* Family -> Sibling	7	15s
Birth↔Health	3	10s	Sibling -> Love	7	15s
* Death↔Human	3	10s	* Water -> Sea	7	15s
* Death↔Old_age	3	10s	Sun -> Oxygen	6	16s
Death↔Sorrow	3	10s	* Animal -> Human	6	16s
* Death↔War	3	10s	* Animal -> Nature	6	16s
Dog↔Family	3	10s	Human -> Happiness	6 (5)	16s
Dog↔Pet	3	10s	* Plant -> Nature	6	16s
* Education↔School	3	10s	Plant -> Light	6	16s
Family↔House	3	10s	* School -> Education	6	16s

Family⇄Joy	3	10s	* Education -> School	6	16s
Family⇄Work	3	10s	Education -> Adolescence	6	16s
* Food⇄Health	3	10s	Education -> Leisure	6	16s
Food⇄Living	3	10s	Death -> Organism	6	16s
Friendship⇄Party	3	10s	* Death -> Human	6	16s
Ground⇄Water	3	10s	* Child -> Family	6	16s
* Happiness⇄Love	3	10s	Teacher -> Learning	6	16s
Hobby⇄Leisure	3	10s	* Family -> Child	6	16s
Hobby⇄School	3	10s	Peace -> Education	6	16s
* Home⇄House	3	10s	Diet_(nutrition) -> Organism	6	16s
Home⇄School	3	10s	Heart -> Organism (only to roll back)	6	16s
Home⇄Work	3	10s	* Mother -> Love	6	16s
Living⇄Religion	3	10s	Biology -> Human	5	17s
Living⇄School	3	10s	Human -> War	5 (3)	17s
Living⇄Water	3	10s	God -> Father	5	17s
* Nature⇄Sun	3	10s	Education -> Human	5	17s
School⇄Study	3	10s	Education -> Teacher	5	17s
* Adolescence⇄Friendship	2	11s	Death -> Heart	5	17s
Animal⇄Environment	2	11s	Child -> Adolescence	5	17s
Animal⇄God	2	11s	* Teacher -> School	5	17s
Animal⇄Tree	2	11s	Tree -> Oxygen	5	17s
Atmosphere_of_Earth⇄Ground	2	11s	Love -> Biology	5	17s
Automobile⇄Family	2	11s	Heart -> Death (only to roll back)	5	17s
Automobile⇄House	2	11s	Health -> Biology	5	17s
Birth⇄Child	2	11s	Work -> Leisure (only to roll back)	5	17s
Birth⇄Family	2	11s	Religion -> God	5	17s
Birth⇄Growing	2	11s	Light -> Sun	5	17s
Birth⇄Human	2	11s	Parent -> Human	5	17s
Birth⇄Nature	2	11s	Parent -> Birth	5	17s
Book⇄School	2	11s	Leisure -> Work	5	17s
Chair⇄House	2	11s	Animal -> Organism	4	18s
Child⇄Hospital	2	11s	Father -> Love	4	18s
Child⇄Human	2	11s	* School -> Teacher	4	18s
Clock⇄Computer	2	11s	Child -> Parent	4	18s
Clock⇄School	2	11s	* Nature -> Animal	4	18s
Clothing⇄Shoe	2	11s	* Nature -> Human	4	18s
Computer⇄Leisure	2	11s	Adolescence -> Old_age	4	18s
Death⇄Nature	2	11s	* Happiness -> Love	4	18s
Diet_(nutrition)⇄Water	2	11s	* Family -> Father	4	18s
* Disease⇄Health	2	11s	Family -> Leisure	4	18s
Dream⇄Health	2	11s	War -> Religion	4	18s
Education⇄Living	2	11s	Health -> Diet_(nutrition)	4	18s
* Emotion⇄Love	2	11s	Leisure -> Family	4	18s
Environment⇄Family	2	11s	Water -> Sun	4	18s
Environment⇄Nature	2	11s	Oxygen -> Sun	3	19s
Experience⇄Work	2	11s	Oxygen -> Disease	3	19s
Family⇄Health	2	11s	* Human -> Love	3 (2)	19s
Family⇄Hobby	2	11s	Human -> Religion	3 (0)	19s
Family⇄Money	2	11s	Human -> Clothing	3 (2)	19s
Family⇄Pet	2	11s	* Father -> Family	3	19s
* Family⇄Sibling	2	11s	Plant -> Organism	3	19s
Family⇄Study	2	11s	Plant -> Water	3	19s
Family⇄Telephone	2	11s	* Nature -> Sun	3	19s
Father⇄Home	2	11s	Nature -> Organism	3	19s
Food⇄Television	2	11s	Nature -> Oxygen	3	19s
Friendship⇄Leisure	2	11s	* Nature -> Plant	3	19s
Friendship⇄Living	2	11s	Travel -> Water	3	19s
Friendship⇄Pet	2	11s	Adolescence -> Television	3	19s
Friendship⇄Sibling	2	11s	Learning -> Teacher (only to roll back)	3	19s
Friendship⇄Study	2	11s	Diet_(nutrition) -> Death	3	19s
Friendship⇄Work	2	11s	Sibling -> Parent	3	19s
God⇄Organism	2	11s	War -> Disease	3	19s
Ground⇄Nature	2	11s	Birth -> Animal	3	19s
Health⇄Light	2	11s	Television -> Adolescence (only to roll back)	3	19s

Health⇨Old_age	2	11s	Religion -> Human	3	19s
Health⇨Physical_fitness	2	11s	* Old_age -> Death	3	19s
Heart⇨Love	2	11s	* Water -> Oxygen	3	19s
Hobby⇨Work	2	11s	Water -> Plant	3	19s
Holiday⇨Party	2	11s	Water -> Travel	3	19s
Holiday⇨Work	2	11s	Automobile -> Oxygen	2	20s
Home⇨Mother	2	11s	Biology -> Plant	2	20s
House⇨Work	2	11s	Biology -> Health	2	20s
Joy⇨Living	2	11s	Oxygen -> Automobile	2	20s
Joy⇨Love	2	11s	Oxygen -> Heart	2	20s
Learning⇨Love	2	11s	Human -> Oxygen	2 (1)	20s
* Leisure⇨Television	2	11s	Human -> House	2 (1)	20s
Living⇨Music	2	11s	Father -> Parent	2	20s
Living⇨Organism	2	11s	* Father -> Mother	2	20s
Living⇨Peace	2	11s	Plant -> Biology	2	20s
Living⇨Purpose	2	11s	Plant -> Animal	2	20s
Living⇨Sorrow	2	11s	Plant -> Oxygen	2	20s
Living⇨Sun	2	11s	* Home -> Family	2	20s
Living⇨Travel	2	11s	Education -> Biology	2	20s
* Love⇨Mother	2	11s	Death -> Oxygen	2	20s
Love⇨Nature	2	11s	Tree -> Water	2	20s
Love⇨Parent	2	11s	Peace -> War	2	20s
Nature⇨Tree	2	11s	* Sibling -> Family	2	20s
* Oxygen⇨Water	2	11s	* House -> Home	2	20s
* School⇨Teacher	2	11s	Religion -> Sun	2	20s
* Sea⇨Water	2	11s	Clothing -> Religion	2	20s
Summer⇨Sun	2	11s	Light -> Television	2	20s
			Parent -> Father	2	20s
			Parent -> Child	2	20s
			Parent -> Sibling	2	20s
			Leisure -> Education	2	20s
			Leisure -> Sibling	2	20s
			Water -> Biology	2	20s
			Friendship -> Animal	2	20s
			* Friendship -> Love	2	20s
			* Mother -> Father	2	20s
			Animal -> Oxygen	1	21s
			Animal -> Water	1	21s
			* Human -> Animal	1 (0)	21s
			Human -> Music	1 (1)	21s
			Father -> Sibling	1	21s
			Education -> Sibling	1	21s
			Child -> Old_age	1	21s
			Child -> Leisure	1	21s
			Teacher -> Education	1	21s
			Diet_(nutrition) -> Religion	1	21s
			Food -> Human	1	21s
			Disease -> Oxygen (only to roll back)	1	21s
			* Birth -> Death	1	21s
			Birth -> Mother	1	21s
			Television -> Clothing (only to roll back)	1	21s
			Television -> Light (only to roll back)	1	21s
			* Television -> Leisure (only to roll back)	1	21s
			* Health -> Food	1	21s
			Clothing -> Television	1	21s
			Parent -> Mother	1	21s
			Old_age -> Adolescence	1	21s
			* Leisure -> Television	1	21s
			Water -> Human	1	21s
			* Mother -> Family	1	21s

Appendix O

These listings shows three key vocabularies, containing only nouns, generated for preliminary testing of proposed method of publication [P6] performed based on simple learning scenarios about children aiming to adopt basic vocabulary used in everyday life. In all key vocabularies the ranking values for each noun indicates its position among all highest-ranking nouns and thus words other than nouns are not considered.

The key vocabularies of learner's knowledge and learning objective consisted of the highest-ranking 10 percent of the nouns in text samples provided by the learner and the Wikipedia article respectively about selected topics. In listings shown here key vocabulary of learner's knowledge is based on the highest-ranking nouns occurring in a text sample generated by a test user in May 2010 about topic "child" and key vocabulary of learning objective is based on high-frequency words of Wikipedia article "Child" (relying on Wikipedia article version on 20 May 2010).

The key vocabulary of learning context consisted of 100 highest-ranking nouns used by English speaking children queried from Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) for combination of early educational levels denoted by "Rec/Prep/K" that we will refer to as school level Preparatory (<http://www.oxfordwordlist.com/pages/search.asp>). Thus when querying the key vocabulary of learning context the following settings were used: school year was "Rec/Prep/K" and language was "English speaking" and for other settings concerning gender, indigeneous, school setting, location and text type an option "any" was used.

In the Wikipedia both entry Sister and entry Brother are redirected to shared article Sibling and thus in the Wikipedia word "sibling" can be considered to represent both words "brother" and "sister". Thus in key vocabularies of learner's knowledge and learning context words "brother" and "sister" have a shared corresponding Wikipedia article Sibling, indicated with an asterisk (*) in listings below. It was considered that in key vocabulary of learning objective words "criminal" and "imprisonment" cover related themes and thus "imprisonment" was combined with "criminal" and thus they have a shared corresponding Wikipedia article Crime, indicated with an double asterisk (**) in listings below.

When generating key vocabulary of learning context based on highest-ranking nouns of Oxford Wordlist numerals were excluded (in contrast with key vocabulary of learning objective) and word "fun", that would have been positioned in ranking listing between "day" and "play", was excluded (in contrast with the emergence of concept Fun in other analysis, for example among core concepts, see Appendix F) and word "can" was included as a noun form although we assume that "can" has gained its high-ranking position in Oxford Wordlist due to its verb form. Sequences of words in alphabetical and non-alphabetical order in Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) (<http://www.oxfordwordlist.com/pages/search.asp>) made us to suggest that perhaps some of the ranking values should be considered as shared ranking values. It remained as an open question if some of ranking values of Oxford Wordlist (in column indicated with a triple asterisk (***) in listing below) should be shared and finally we decided to give individual ranking value that increase one by one to all words in our listing of key vocabulary of learning context (i.e. no shared ranking values were used).

Key vocabulary of learner's knowledge			Key vocabulary of learning objective			Key vocabulary of learning context		
Concept	The closest matching entry of Wikipedia article	Ranking	Concept	The closest matching entry of Wikipedia article	Ranking	Concept	The closest matching entry of Wikipedia article	Ranking***
girl	Girl	1	child	Child	1	weekend	Weekend	1
boy	Boy	2	age	Age	2	dad	Father	2
school	School	3	country	Country	3	home	Home	3
kindergarten	Kindergarten	4	attitude	Attitude	4shared	house	House	4
protection	Protection	5	time	Time	4shared	mum	Mother	5
laugh	Laughter	6	group	Group	5shared	time	Time	6
cry	Cry	7	marriage	Marriage	5shared	day	Day	7
worry	Worry (emotion)	8	year	Year	5shared	play	Play_(disambiguation)	8
joy	Joy	9	action	Action	6shared	park	Park	9
color	Color	10	adhd	Attention_deficit_hyperactivity_disorder	6shared	birthday	Birthday	10
ball	Ball	11	criminal**	Crime**	6shared	Saturday	Saturday	11
sandbox	Sandbox	12	education	Education	6shared	party	Party	12
game	Game	13	human	Human	6shared	Sunday	Sunday	13
square	Square	14	imprisonment**	Imprisonment**	(imprisonment combined with criminal, thus shared corresponding Wikipedia article Crime)	dog	Dog	14
backpack	Backpack	15	law	Law	6shared	brother*	Sibling*	15
		16	learning	Learning	6shared	football	Football	16
baby	Infant	17	majority	Majority	6shared	friends	Friendship	17
home	Home	18	play	Play (disambiguation)	6shared	can	Can	18
father	Father	19	seven	7 (number)	6shared	love	Love	19
mother	Mother	20	skill	Skill	6shared	zoo	Zoo	20
sister*	Sibling*	21	stage	Stage	6shared	school	School	21
brother*	Sibling*	(already above)	way	Way	6shared	playing	Play_(activity)	22
			world	World	6shared	night	Night	23
						bed	Bed	24
						shop	Shop	25
						bike	Bike	26
						dinner	Dinner	27
						car	Automobile	28
						fish	Fish	29
						beach	Beach	30
						sister*	Sibling*	(already above)
						name	Name	31
						people	People	32
						movies	Film	33
						water	Water	34
						book	Book	35
						Friday	Friday	36
						toy	Toy	37
						shark	Shark	38
						family	Family	39
						playground	Playground	40
						tv	Television	41
						buddy	Buddy	42
						cat	Cat	43

						lunch	Luncheon	44
						yesterday	Yesterday	45
						girl	Girl	46
						icecream	Ice_cream	47
						swimming	Swimming	48
						baby	Infant	49
						holidays	Holiday	50
						ride	Ride	51
						dinosaur	Dinosaur	52
						game	Game	53
						present	Present	54
						slide	Slide	55
						ball	Ball	56
						shopping	Shopping	57
						chips	Chip_(disambiguation)	58
						food	Food	59
						work	Work	60
						footy	Footy	61
						magic	Magic	62
						mermaid	Mermaid	63
						rabbit	Rabbit	64
						soccer	Association_football	65
						dragon	Dragon	66
						fairy	Fairy	67
						hair	Hair	68
						boat	Boat	69
						cousin	Cousin	70
						jungle	Jungle	71
						riding	Riding	72
						zebra	Zebra	73
						animals	Animal	74
						cake	Cake	75
						castle	Castle	76
						chocolate	Chocolate	77
						horse	Horse	78
						Monday	Monday	79
						morning	Morning	80
						pool	Pool	81
						room	Room	82
						sea	Sea	83
						sleepover	Sleepover	84
						today	Today	85
						breakfast	Breakfast	86
						garden	Garden	87
						monkey	Monkey	88
						monster	Monster	89
						outside	Outside	90
						show	Show	91
						week	Week	92
						computer	Computer	93
						inside	Inside	94
						lion	Lion	95
						parade	Parade	96
						pirate	Piracy	97
						snake	Snake	98
						tiger	Tiger	99

Appendix P

Listing that shows the highest-ranking words (only common nouns) gathered in our experiment from teenaged students (n=103) when they were asked to list and rank most significant vocabulary concerning topic “life”. This listing shows high-frequency words with ranking based on occurrences in word lists of 20 words generated by students (each student could mention each concept at most once in her word list).

Following rule was used when generating this listing: for each concept at most one occurrence is counted per student, and if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position (notation suffix -s indicates shared ranking position).

Notation containing slash symbol (/) separating two concepts is used when a word gathered from students was considered to have more than one possible dominating form of interpretation or translation. Although excluded from the list below since not qualified as suitable common nouns, students mentioned in their word lists two specific languages, including 7 occurrences for Finnish and 1 occurrence for German.

Ranking	Concept in English	Concept in Finnish	Occurrences
1	family	perhe	53
2	friend	ystävä	49
3	work	työ	41
4	death	kuolema	40
5.5s	love; school	rakkaus; koulu	33
7.5s	food; water	ruoka; vesi	31
9	animal	eläin	29
10	human	ihminen	24
11	birth	syntymä	23
12	nature	luonto	21
13	home	koti	18
15s	child; joy; sun	lapsi; ilo; aurinko	16
18s	dog; hobby; house	koira; harrastus; talo	15
22s	education; health; money; sorrow; study	koulutus; terveys; raha; suru; opiskelu	14
25	computer	tietokone	13
26	plant	kasvi	12
28s	car; happiness; tree	auto; onnellisuus; puu	11
30.5s	book; cat	kirja; kissa	10
34.5s	air; clock; learning; mother; summer; television	ilma; kello; oppiminen; äiti; kesä; televisio	9
39.5s	living; music; party; religion	eläminen; musiikki; juhla; uskonto	8
46.5s	city; cloth; elderness; environment; father; freetime; holiday; light; pet; world	kaupunki; vaate; vanhuus; ympäristö; isä; vapaa-aika; loma; valo; lemmikki; maailma	7
58s	childhood; disease; emotion; experience; fun; ground/Earth; growing; hate; heart; paper; sea; shoe; sport	lapsuus; sairaus; tunne; kokemus; hupi; maa; kasvaminen; viha; sydän; paperi; meri; kenkä; urheilu	6
71.5s	baby; biology; eating; flower; forest; god; goodness; peace; pen/pencil; philosophy; purpose; succeeding; war; young (person)	vauva; biologia; syöminen; kukka; metsä; jumala; hyvyys; rauha; kynä; filosofia; tarkoitus; onnistuminen; sota; nuori	5
90.5s	bed; bread; chair; dream (sleeping); pleasure; evolution; exam; future; goal (to achieve); hospital; marriage; nutriment; organism; oxygen; parent; people; phone; physical training; rain; sadness; sister; teacher; time; travel	sänky; leipä; tuoli; uni; nautinto; evoluutio; koe; tulevaisuus; tavoite; sairaala; avioliitto; ravinto; eliö; happi; vanhempi; ihminen (ryhmä); puhelin; liikunta; sade; surullisuus; sisko; opettaja; aika; matka	4
128s	adulthood; art; bird; blood; breath; breathing; brother; career; cell; culture; dance; dating; difference; disappointment; dna; dream (wishing); drink; earth; economy; fire; freedom; gift; greenness; hardness; ice cream; laugh; leaf/newspaper; learning content; life cycle; lifestyle; luck; moral; notebook; pain; problem; relationship; relative; reproduction; science; sky/heaven; smallness; sociality; spirit; suffering; travelling; weather; wheel/bicycle; wife; working place; year; youth	aikuisuus; taide; lintu; veri; hengitys; hengitys; veli; ura; solu; kulttuuri; tanssi; seurustelu; erilaisuus; pettymys; dna; unelma; juoma; maapallo; talous; tuli; vapaus; lahja; vihreys; kovuus; jäätelö; nauru; lehti; oppi; elämänkaari; elämäntapa; onni; moraali; vihko; tuska; ongelma; suhde; sukulainen; lisääntyminen; tiede; taivas; pienuus; sosiaalisuus; henki; kärsimys; matkustaminen; sää; pyörä; vaimo; työpaikka; vuosi; nuoruus	3
198s	accessory; achievement; adult; age; apartment; autumn; ball; beach; bear; beer; being; being alive;	varuste; saavutus; aikuinen; ikä; asunto; syksy; pallo; ranta; karhu; olut; oleminen;	2

	<p>belief; bigness; boy; boyfriend; brain; butter; change; closeness; confirmation_school_(religion); dad; day; difficulty; elder; electricity; end; enjoying; evilness; eyeglasses; foreign_country; friendship; girl; history; honey; horse; identity; importance; information; internet; justice; lamp; law; loneliness; loveliness; match_(for firing); material; meaning; mobile_phone; motorcycle; moving; niceness; night; old; outer_space; park; performance; person; planet; possibility; prison; roof; rose; senior_house; sense; separation/divorce; sex; shirt; shop; sibling; smile; song; spring; stress; success; sunlight; table; tax; tobacco; transition; trap; trousers; universe; versatility; victory; wedding; wish; wolf; yard_(garden)</p>	<p>elossaoleminen; uskomus; suuruus; poika; poikaystävä; aivot; voi; muutos; läheisyys; rippikoulu; isä; päivä; vaikeus; vanhus; sähkö; loppu; nauttiminen; pahuus; silmälasit; ulkomaa; ystävyys; tyttö; historia; hunaja; hevonen; identiteetti; tärkeys; tieto; internet; oikeus; lamppu; laki; yksinäisyys; ihanuus; tulitikku; aine; merkitys; kännykkä; moottoripyörä; liikkuminen; somuus; yö; vanha; ulkoavaruus; puisto; suoritus; henkilö; planeetta; mahdollisuus; vankila; katto; ruusu; vanhainkoti; aisti; ero; seksi; paita; kauppa; sisarus; hymy; laulu; kevät; stressi; menestys; auringonvalo; pöytä; vero; tupakka; siirtymä; ansa; housut; maailmankaikkeus; monipuolisuus; voitto; häät; toive; susi; piha</p>	
432s	<p>accident; activity; admiration; adolescence; adrenaline; adventure; adversity; agreement; angel; anger; animal_kingdom; arc; assignment; atom; attitude; awesomeness; baptism_ceremony; bacteria; badness; bag; balance; bank_(money); bar_(restaurant); basket_ball; beauty; beginning; behavior; being_(person/animal); being_together; belonging; bill_(payment); biodiversity; biologist; birch; birthday; body; body-training; bond_(economics); bow_tie; bug; building; bush; calmness; camp; candle; candy; care; carrot; catastrophe; cave; cell_phone; challenge; cheese; chicken; christmas; church; cider; circulation_(rotation); class; climax; climbing; closet; costume; cloud; coal; coffee; coffee_cup; coffin; colonization; color; combat; community; competition; complicatedness; confidence; conscience; consumer; convenience; cottage; countryside; couple; course; criminal; cross_(symbol); cruelty; darkness; dead; death_penalty; decomposer; defeat; degree_(diploma); depressiveness; development; diagnose; dirtiness; disc; diversity; doctor_(physician); drinking; driving_licence; duck; duty; easy; easiness; ecosystem; effort; electronics; energy; engagement_(prior_wedding); entertainment; eraser; eternity; event; expedition; exploration; fail; family_(relatives); farm_(farmhouse); fashion; fastness; scare; scariness; feeling; fence; film; fishery; flame; flute; flying; fog; football; forty-two; freedom_of_speech; fruit; fulfillment; funeral; funniness; fur; futility; game; gender; gene; getting_along; getting_dumber; getting_things_done; getting_wiser; ghost; giraffe; girlfriend; glacier; globalization; godship; golf; government; grandmother; grass_(lawn); greatness; guess; guitar; habit; hair; hairspray; ham; handsomeness; hatred; having_fun; head; heaven; hecticness; hedgehog; helping; heredity; heritage; home_country; homework; honesty; hope; hotness; household_work; human_relationship; hurting; ideology; injustice; ink; interactiveness; item; joke; kindergarten; kindness; knowing; knowledge; lake; laptop; lawn; leaf_of_lettuce; life-givingness; lifetime; lighter_(for_firing); limitedness; living_region; living_room; long_time; longing; longness; loss; loudspeaker; lungs; machine; mad; magic; mammal; man; mandatoriness; marine_life; market_(economics); massacre; meat; medicine_(discipline); medicine_(healing_chemical); memory; mental_development; middle-ageness; milk; mind; minister_(politics); minute; miracle; misery; misfortune; molecule; moment; moon; mountain; mouse; movie; moving_(changing_location_of_home); mp3_player; nailpolish; naturalness; need; neighbor; nightclub; noise; normality; ocean; organ; organs_(entity); outlook; passing_time; passion; past; patriotism; pelvis; pencil_case; pension; period; personality; phoenix; photosynthesis; physicality; physics; plane; play_age; playing_(sports/game); politics; pool_(small_lake); potential; predator; pregnancy; president; prey; privacy; producer; property;</p>	<p>onnettomuus; toiminta; ihailu; nuoruus; adrenaliini; seikkailu; vastoinkäyminen; sopimus; enkeli; vihaisuus; eläinkunta; kaari; tehtävä; atomi; asenne; hurjuus; kastejuhla; bakteeri; huonous; laukku; tasapaino; pankki; baari; koripallo; kauneus; alku; käytös; olento; yhdessäolo; kuuluvuus; lasku; luonnon_monimuotoisuus; biologi; koivu; syntymäpäivä; ruumis; kehonrakennus; joukkovelkakirja; rusetti; ötökkä; rakennus; pensas; rauhallisuus; leiri; kynttilä; makeinen; hoito; porkkana; katastrofi; luola; matkapuhelin; haaste; juusto; kana; joulukirkko; siideri; kiertokulku; luokka; huippukohta; kiipeäminen; kaappi; asu; pilvi; hiili; kahvi; kahvikuppi; arkku; löytöretkeily; väri; kamppailu; yhteisö; kilpailu; mutkikkuus; tyytyväisyys; omatunto; kuluttaja; mukavuus; mökki; maaseutu; pari/pariskunta; kurssi; rikollinen; risti; julmuus; pimeys; kuollut; kuolemanrangaistus; hajottaja; häviö; tutkinto; masentavuus; kehitys; diagnoosi; likaisuus; kiekko; monimuotoisuus; lääkäri; juominen; ajokortti; ankkuri; velvollisuus; helppo; helppous; ekosysteemi; ponnistelu; elektroniikka; energia; kihlat; viihde; kumi; ikuisuus; tapahtuma; tutkimusmatka; tutkiminen; epäonnistuminen; suku; maatila; muoti; nopeus; pelko; pelottavuus; tuntemus; aita; filmi; kalastusyhtiö; liekki; huilu; lentäminen; sumu; jalkapallo; neljäkymmentäkaksi; sananvapaus; hedelmä; täyttymys; hautajaiset; huvittavuus; turkki; turhuus; peli; sukupuoli; geenit; viihtyvyys; tyhmistyminen; aikaansaavuus; viisastuminen; haamu; kirahvi; tyttöystävä; jäätikkö; globalisoituminen; palvonta; golf; eduskunta; isoäiti; ruoho; suurenmoisuus; veikkaus; kitara; tapa; hiukset; hiuslakka; kinkku; komeus; vihaisuus; hauskanpito; pää; taivas; hehtisyys; siili; auttaminen; perinnöllisyys; perintö; kotimaa; läksyt; rehellisyys; toivo; kuumuus; kotitalous; ihmissuhde; sattuminen_(kipu); ideologia; epäoikeudenmukaisuus; muste; vuorovaikutteisuus; kappale; vitsi; tarha; ystävällisyys; tietäminen; tietämys; järvi; kannettava; nurmikko; salaatinlehti; elämän_mahdollistaminen; elinaika; syytin; rajallisuus; asuinpaikka; olohuone; pitkä_aika; kaipaaminen; pituus; menetys; kaiutin; keuhkot; kone; mielipuolinen; taika; nisäkäs; mies/ihminen; pakollisuus; merellinen_elämä; markkinat; joukkotuho; liha; lääketiede; lääke; muisto; henkinen_kehitys; keski-ikäisyys; maito; mieli; ministeri; minuutti; ihme; kurjuus; epäonni; molekyyli; hetki; kuu; vuori; hiiri; elokuva; muutto; mp3-soitin; kynsilakka; luonnollisuus; tarve; naapuri; yökerho; melu; tavallisuus; valtameri; elin; elimistö; katsomus; ajan_viettäminen; intohimo; menneisyys; isänmaanrakkaus;</p>	1

	<p>property_(belongings); question; reading; realisticness; reason; record_(new_achievement); rectangle; regeneration; relaxing; residing; respect; responsibility; rna; road; robot; rock_'n_roll; rock_(ground_material); room_(in_apartment); satisfaction; school_institution; sealife; senate; sharpener_(for_pencils); shelf; shelter; shine; shortness; shower; sign; silence; singing; single-home_house; ice skate; skateboard; skill; sky; sleeping; slowness; snow; snowboard; social_life; sock; sofa; soul; space; spirituality; spoon; spouse; square; star; start; stock_(economics); strangeness; string_(of_clothing); string_of_life; study book; style; suicide; sunshine; surfboard; survival; surviving; survivor; suspense; swimming; talent; target_of_attention; teaching; teaching_children; technology; teen; tennis; thing; thinking; thought; tiger; tradition; trip; ugliness; undersea; understanding; uneven; unfairness; uniqueness; value; variation; videogame_device; view_(opinion); vitamin; vocation; volleyball; volcano; walking; wall_(of_room); warmth; weekday; weirdness; well-being; window; winter; woman; wonderfulness; worry; writing; zebra</p>	<p>lonkka; penaali; eläke; valhe; persoona; feeniks; fotosynteesi; fyysisyys; fysiikka; lentokone; leikki-ikä; pelaaminen; politiikka; lampi; valmius; peto; raskaus; presidentti; saalis; yksityisyys; tuottaja; omaisuus; omaisuus; kysymys; lukeminen; todenmukaisuus; syy; ennätys; ruutu; uusiutuminen_(regeneraatio); rentoutuminen; asuminen; kunnioittaminen; vastuuntunto; ma; tie; robotti; rock_'n_roll; kallio; huone; tyydytys; koululaitos; merielämä; hallitus; teroitin; hylly; suoja; paiste; lyhyys; suihku; merkki; hiljaisuus; laulaminen; omakotitalo; luistin; skeittilauta; taito; taivas; nukkuminen; hitaus; lumi; lumilauta; sosiaalinen_elämä; sukka; sohva; sielu; avaruus/tila; hengellisyys; lusikka; puoliso; neliö; tähti; alku; osake; outous; lanka; elämänlanka; oppikirja; tyyli; itsemurha; auringonpaiste; surffilauta; selviytyminen; selviytyminen; selviytyjä; jännitys; uiminen; kyky; mielenkiinnon_kohde; opetus; lastenkasvatus; teknologia; teini; tennis; asia/esine; ajattelu; ajatus; tiikeri; perinne; retki; rumuus; merenalainen; ymmärtäminen; epätasaisuus; vääryys; ainutlaatuisuus; arvo; vaihtelevuus; videopelilaitte; näkemys; vitamiini; kutsumus; lentopallo; tulivuori; käveleminen; seinä; lämpö; arki; omituisuus; hyvinvointi; ikkuna; talvi; nainen; suurenmoisuus; huoli; kirjoittaminen; seepra</p>	
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Appendix Q

This list shows the high-frequency words (only common nouns) gathered in our experiment from teenaged students (n=103) when they were asked to list and rank most significant vocabulary concerning topic “life”. This list shows high-frequency words with ranking based on sum of “measures of importance” originating from ranking given by each student for the words she generated to form her word list of 20 words (ranking values of “measure of importance” originally given by students in ascending range from 1 to 20 were translated to an inverse descending range of measures of importance from 21 to 1, thus greater value now indicating more important).

Following rule was used when generating the list: for each concept we counted together all “measure of importance” values, and if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position (notation suffix -s indicates shared ranking position).

Notation containing slash symbol (/) separating two concepts is used when a word gathered from students was considered to have more than one possible dominating form of interpretation or translation. Although excluded from the list below since not qualified as suitable common nouns, for two specific languages students mentioned in their word lists sum of measures of importance for Finnish was 76 (corresponding to about ranking 50.5s) and for German 3 (corresponding about ranking 541s).

Ranking	Concept in English	Concept in Finnish	Sum of measures of importance
1	family	perhe	903
2	friend	ystävä	821
3	love	rakkaus	525
4	work	työ	445
5	water	vesi	408
6	food	ruoka	396
7	death	kuolema	363
8	school	koulu	362
9	human	ihminen	335
10	birth	syntymä	321
11	nature	luonto	303
12	animal	eläin	285
13	home	koti	237
14	health	terveys	225
15	sun	aurinko	224
16	child	lapsi	202
17	joy	ilo	195
18	hobby	harrastus	188
19	study	opiskelu	186
20	happiness	onnellisuus	179
21	education	koulutus	172
22	house	talo	147
23	plant	kasvi	136
24	mother	äiti	133
25	money	raha	130
26	air	ilma	121
27	dog	koira	118
28	world	maailma	106
29.5s	father; living	isä; eläminen	105
31	sorrow	suru	104
32	learning	oppiminen	103
33.5s	book; computer	kirja; tietokone	99
35	clock	kello	98
36	cloth	vaate	95
38s	freetime; holiday; music	vapaa-aika; loma; musiikki	91
40	party	juhla	87
41	emotion	tunne	86

43s	fun; summer; tree	hupi; kesä; puu	85
45.5s	purpose; television	tarkoitus; televisio	84
47.5s	car; heart	auto; sydän	80
49	oxygen	happi	79
50.5s	childhood; parent	lapsuus; vanhempi	76
52	environment	ympäristö	75
53	ground/Earth	maa	74
54	baby	vauva	73
55	growing	kasvaminen	72
56	peace	rauha	71
57	goodness	hyvyys	70
58	eating	syöminen	69
59.5s	light; travel	valo; matka	67
61	experience	kokemus	66
63s	goal_(to_achieve); pet; succeeding	tavoite; lemmikki; onnistuminen	64
65.5s	religion; sport	uskonto; urheilu	62
67	nutriment	ravinto	61
68	elderness	vanhuus	60
70s	cat; forest; god	kissa; metsä; jumala	59
72	future	tulevaisuus	58
73	brother	veli	56
74	time	aika	55
75.5s	luck; physical_training	onni; liikunta	54
77	dream_(sleeping)	uni	53
79.5s	city; pleasure; philosophy; shoe	kaupunki; nautinto; filosofia; kenkä	52
82.5s	learning_content; marriage	oppi; avioliitto	51
84	bread	leipä	49
85	sea	meri	48
87.5s	difference; dream_(wishing); flower; phone	erilaisuus; unelma; kukka; puhelin	47
90	dance	tanssi	46
91.5s	moral; working_place	moraali; työpaikka	45
94.5s	bed; biology; blood; reproduction	sänky; biologia; veri; lisääntyminen	44
97	breathing	hengitys	42
98.5s	organism; people	eliö; ihminen_(ryhmä)	41
100	person	henkilö	40
102s	boyfriend; cell; gift	poikaystävä; solu; lahja	39
104.5s	hospital; sociality	sairaala; sosiaalisuus	38
107s	evolution; possibility; travelling	evoluutio; mahdollisuus; matkustaminen	37
109.5s	greenness; victory	vihreys; voitto	36
115s	career; closeness; drink; horse; laugh; relationship; science; spirit; universe	ura; läheisyys; juoma; hevonen; nauru; suhde; tiede; henki; maailmankaikkeus	35
121.5s	art; pain; rain; teacher	taide; tuska; sade; opettaja	34
126.5s	adulthood; butter; identity; pen/pencil; versatility; wedding	aikuisuus; voi; identiteetti; kynä; monipuolisuus; häät	33
133.5s	adult; justice; paper; sadness; sense; sibling; sister; suffering	aikuinen; oikeus; paperi; surullisuus; aisti; sisarus; sisko; kärsimys	32
139.5s	brain; freedom; relative; senior_house	aivot; vapaus; sukulainen; vanhainkoti	31
144.5s	exam; hate; importance; wheel/bicycle; year; young_(person)	koe; viha; tärkeys; pyörä; vuosi; nuori	30
148	dna	dna	29
150s	disease; disappointment; trousers	sairaus; pettymys; housut	28
153s	moving; war; wife	liikkuminen; sota; vaimo	27
158s	autumn; history; internet; law; shirt; sky/heaven; success	syksy; historia; internet; laki; paita; taivas; menestys	26
164s	culture; economy; ice_cream; leaf/newspaper; planet	kulttuuri; talous; jäätelö; lehti; planeetta	25
168s	meaning; outer_space; song	merkitys; ulkoavaruus; laulu	24
172s	achievement; bird; boy; confirmation_school_(religion); end	saavutus; lintu; poika; rippikoulu; loppu	23
177s	apartment; being_alive; earth; sex; wish	asunto; elossaoleminen; maapallo; seksi; toive	22
185.5s	arc; bigness; dating; fulfillment; funniness; long_time; man; niceness; rock_'n_rol; surfboard; technology; wonderfulness	kaari; suuruus; seurustelu; täyttymys; huvittavuus; pitkä_aika; mies/ihminen; somuus; rock_'n_rol; surffilauta; teknologia; suurenmoisuus	21
200s	age; beauty; being; belief; care; dad; difficulty; girlfriend; golf; reason; roof; silence; smallness; snowboard; survivor; tiger; youth	ikä; kauneus; oleminen; uskomus; hoito; isä; vaikeus; tyttöystävä; golf; syy; katto; hiljaisuus; pienuus; lumilauta; selviytyjä; tiikeri; nuoruus	20
218s	being_together; coal; development; doctor_(physician); freedom_of_speech; gene; getting_wiser; head; hecticness; ideology; injustice; life_cycle; machine; organ; period; physicality; ice skate; ugliness; woman	yhdessäolo; hiili; kehitys; lääkäri; sananvapaus; geeni; viisastuminen; pää; hektisyys; ideologia; epäoikeudenmukaisuus; elämänkaari; kone; elin; valhe; fyysisuus; luistin; rumuus; nainen	19
242s	adventure; biologist; confidence; couple; cross_(symbol); cruelty; dead; dirtiness; ecosystem; electricity; eternity; family_(relatives); feeling; friendship; getting_things_done; loneliness; medicine_(discipline);	seikkailu; biologi; tyytyväisyys; pari/pariskunta; risti; julmuus; kuollut; likaisuus; ekosysteemi; sähkö; ikuisuus; suku; tuntemus; ystävyys; aikaansaavuus; yksinäisyys; lääketiede; henkinen_kehitys; maito;	18

	mental_development; milk; old; past; school_institution; sealife; social_life; spirituality; star; tradition; transition; zebra	vanha; menneisyys; koululaitos; merielämä; sosiaalinen_elämä; hengellisyys; tähti; perinne; siirtymä; seepra	
269s	accessory; balance; being_(person/animal); depressiveness; duty; easy; elder; expedition; fastness; game; getting_along; giraffe; girl; home_country; mammal; neighbor; ma; satisfaction; shelter; single-home_house; sleeping; survival; teaching; videogame_device; volleyball	varuste; tasapaino; olento; masentavuus; velvollisuus; helppo; vanhus; tutkimusmatka; nopeus; peli; viihtyvyys; kirahvi; tyttö; kotimaa; nisäkäs; naapuri; ma; tyydytys; suoja; omakotitalo; nukkuminen; selviytyminen; opetus; videopelilaitte; lentopallo	17
290s	activity; belonging; camp; colonization; conscience; diversity; scariness; flame; futility; getting_dumber; having_fun; interactiveness; lifestyle; moment; problem; target_of_attention; weirdness	toiminta; kuuluvuus; leiri; löytöretkeily; omatunto; monimuotoisuus; pelottavuus; liekki; turhuus; tyhmistyminen; hauskanpito; vuorovaikutteisuus; elämäntapa; hetki; ongelma; mielenkiinnon_kohde; omituisuus	16
309.5s	accident; adolescence; animal_kingdom; beginning; candle; circulation_(rotation); color; drinking; enjoying; foreign_country; hardness; human_relationship; laptop; loss; minute; mobile_phone; rose; smile; spouse; stress; undersea; vocation	onnettomuus; nuoruus; eläinkunta; alku; kynttilä; kiertokulku; väri; juominen; nauttiminen; ulkomaat; kovuus; ihmissuhde; kannettava; menetys; minuutti; kännykkä; ruusu; hymy; puoliso; stressi; merenalainen; kutsumus	15
332.5s	atom; breath; bug; exploration; eyeglasses; guitar; information; knowledge; lifetime; loveliness; marine_life; memory; mind; movie; mp3_player; passing_time; privacy; shower; spoon; strangeness; string_of_life; tobacco; view_(opinion); yard_(garden)	atomi; hengitys; ötökkä; tutkiminen; silmälasit; kitara; tieto; tietämys; elinaika; ihanuus; merellinen_elämä; muisto; mieli; elokuva; mp3-soitin; ajan_viettäminen; yksityisyys; suihku; lusikka; outous; elämänlanka; tupakka; näkemys; piha	14
355s	adrenaline; attitude; bag; birthday; body-training; defeat; engagement_(prior_wedding); fashion; fishery; gender; ham; lawn; ocean; organs_(entity); photosynthesis; question; reading; residing; study_book; table; variation	adrenaliini; asenne; laukku; syntymäpäivä; kehonrakennus; häviö; kihlat; muoti; kalastusyhtiö; sukupuoli; kinkku; nurmikko; valtameri; elimistö; fotosynteesi; kysymys; lukeminen; asuminen; oppikirja; pöytä; vaihtelevuus	13
376.5s	bear; cell_phone; combat; community; farm_(farmhouse); fruit; funeral; habit; hairspray; helping; item; massacre; match_(for_firing); moving_(changing_location_of_home); outlook; park; passion; producer; property_(belongings); responsibility; sky; tennis	karhu; matkapuhelin; kamppailu; yhteisö; maatila; hedelmä; hautajaiset; tapa; hiuslakka; auttaminen; kappale; joukkotuho; tulitikku; muutto; katsomus; puisto; intohimo; tuottaja; omaisuus; vastuuntunto; taivas; tennis	12
398.5s	adversity; chicken; class; coffee_cup; competition; globalization; heredity; hope; market_(economics); molecule; motorcycle; personality; property; realisticness; separation/divorce; sign; skateboard; string_(of_clothing); suicide; suspense; thinking; worry	vastoinkäyminen; kana; luokka; kahvikuppi; kilpailu; globalisoituminen; perinnöllisyys; toivo; markkinat; molekyyli; moottoripyörä; persoona; omaisuus; todenmukaisuus; ero; merkki; skeittilauta; lanka; itsemurha; jännitys; ajattelu; huoli	11
418s	admiration; bacteria; beach; candy; chair; criminal; decomposer; grandmother; hotness; ink; meat; pelvis; potential; prison; shine; surviving; thought	ihailu; bakteeri; ranta; makeinen; tuoli; rikollinen; hajottaja; isoäiti; kuumuus; muste; liha; lonkka; valmius; vankila; paiste; selviytyminen; ajatus	10
434s	basket_ball; bush; change; consumer; effort; greatness; household_work; material; misery; need; pension; shop; space; value; weekday	koripallo; pensas; muutos; kuluttaja; ponnistelu; suurenmoisuus; kotitalous; aine; kurjuus; tarve; eläke; kauppa; avaruus/tila; arvo; arki	9
449s	beer; behavior; building; cloud; day; duck; handsomeness; heritage; lake; lungs; nightclub; room_(in_apartment); sock; start; uniqueness	olut; käytös; rakennus; pilvi; päivä; ankka; komeus; perintö; järvi; keuhkot; yökerho; huone; sukka; alku; ainutlaatuisuus	8
465s	agreement; assignment; awesomeness; birch; entertainment; event; fire; glacier; homework; hurting; living_room; longing; night; robot; rock_(ground_material); soul; trap	sopimus; tehtävä; hurjuus; koivu; viihde; tapahtuma; tuli; jäätikkö; läksyt; sattuminen_(kipu); olohuone; kaipa; yö; robotti; kallio; sielu; ansa	7
483.5s	angriness; baptism_ceremony; biodiversity; church; fence; film; heaven; living_region; noise; play_age; politics; record_(new_achievement); road; sunshine; teen; understanding; unfairness; volcano; warmth; weather	vihaisuus; kastejuhla; luonnon_monimuotoisuus; kirkko; aita; filmi; taivas; asuinpaikka; melu; leikki-ikä; politiikka; ennätys; tie; auringonpaiste; teini; ymmärtäminen; väärä; tulivuori; lämpö; sää	6
506s	angel; catastrophe; coffin; complicatedness; cottage; darkness; diagnose; electronics; evilness; fur; longness; mad; medicine_(healing_chemical); miracle; nailpolish; performance; phoenix; physics; playing_(sports/game); singing; skill; sofa; spring; sunlight; swimming	enkeli; katastrofi; arkku; mutkikkuus; mökki; pimeys; diagnoosi; elektroniikka; pahuus; turkki; pituus; mielipuolinen; lääke; ihme; kynsilakka; suoritus; feeniks; fysiikka; pelaaminen; laulaminen; taito; sohva; kevät; auringonvalo; uiminen	5
526s	badness; ball; bank_(money); bill_(payment); countryside; fail; ghost; joke; kindergarten; leaf_of_lettuce; misfortune; pool_(small_lake); relaxing; trip; wall_(of_room)	huonous; pallo; pankki; lasku; maaseutu; epäonnistuminen; haamu; vitsi; tarha; salaatinlehti; epäonni; lampi; rentoutuminen; retki; seinä	4
541s	body; cheese; cider; coffee; course; driving_licence; scare; lighter_(for_firing); mandatoriness; naturalness; notebook; regeneration; shortness; snow; tax	ruumis; juusto; siideri; kahvi; kurssi; ajokortti; pelko; sytytin; pakollisuus; luonnollisuus; vihko; uusiuutuminen_(regeneraatio); lyhyys; lumi; vero	3
555s	bar_(restaurant); bow_tie; carrot; challenge; death_penalty; forty-two; grass_(lawn); honey; lamp; limitedness; magic; mouse; wolf	baari; rusetti; porkkana; haaste; kuolemanrangaistus; neljäkymmentäkaksi; ruoho; hunaja; lamppu; rajallisuus; taika; hiiri; susi	2
591.5s	bond_(economics); calmness; cave; christmas; climax; climbing; closet; costume; convenience; degree_(diploma); disc; easiness; energy; eraser; flute; flying; fog; football; godship; government; guess; hair; hatred; hedgehog; honesty; kindness; knowing; life-givingness; loudspeaker; middle-ageness; minister_(politics); moon; mountain; normality; patriotism; pencil_case; plane; predator; pregnancy; president; prey;	joukkovelkakirja; rauhallisuus; luola; joulu; huippukohta; kiipeäminen; kaappi; asu; mukavuus; tutkinto; kiekko; helppous; energia; kumi; huilu; lentäminen; sumu; jalkapallo; palvonta; eduskunta; veikkaus; hiukset; vihaisuus; siili; rehellisyys; ystävällisyys; tietäminen; elämän_mahdollistaminen; kaiutin; keski-ikäisyys; ministeri; kuu; vuori; tavallisuus; isänmaanrakkaus; penaali; lentokone; peto; raskaus;	1

	rectangle; respect; senate; sharpener_(for_pencils); shelf; slowness; square; stock_(economics); style; talent; teaching_children; thing; uneven; vitamin; walking; well-being; window; winter; writing	presidentti; saalis; ruutu; kunnioittaminen; hallitus; teroitin; hylly; hitaus; neliö; osake; tyyli; kyky; lastenkasvatus; asia/esine; epätasaisuus; vitamiini; käveleminen; hyvinvointi; ikkuna; talvi; kirjoittaminen	
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Appendix R

This table shows heuristically approximated activity frequencies for four collaborator roles of Competing Values Framework in respect to 12 activities that we published in Table 2 of publication [P1] titled “Some approximated relative activity frequencies for each collaborator role”. Please note that in later additional experiments we empirically gained activity frequencies for these activities as show in Table 4.3 in Chapter 4 of current publication and we suggest giving specific attention to those empirically gained values.

<i>Activity</i>	<i>Create role</i>	<i>Compete role</i>	<i>Control role</i>	<i>Collaborate role</i>
Submits ideas	0.40	0.10	0.20	0.30
Adds nodes to concept map	0.40	0.30	0.10	0.20
Adds arcs to concept map	0.20	0.10	0.30	0.40
Makes references to ideas	0.30	0.10	0.40	0.20
Makes references to concept map	0.10	0.30	0.20	0.40
Comments ideas	0.10	0.20	0.40	0.30
Comments concept map	0.30	0.40	0.10	0.20
Sends coordination messages	0.10	0.40	0.20	0.30
Synthesizes ideas to concept map	0.20	0.10	0.40	0.30
Distributes topics from concept map to reconsideration	0.10	0.20	0.30	0.40
Explores accordance of ideas and concept map	0.40	0.30	0.20	0.10
Requests stimulation for creative thinking	0.10	0.40	0.30	0.20

Appendix S

We generated the shortest paths between 10 highest-ranking start concepts (including (occureces in parenthesis): human (121), food (93), water (85), nature (79), entertainment (74), transport (72), nutrition (68), mind (66), infrastructure (65), globalization (63)) and 12 highest-ranking end concepts (including (occureces in parenthesis): animal (108), human (106), water (106), earth (101), mammal (98), psychology (92), philosophy (90), law (86), religion (85), protein (85), science (80), carbon dioxide (80)) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 11.9.

This first listing below shows all 628 shortest routes between 118 pairs of concepts that contained together 1393 hyperlinks of which 736 were unique. Among routes between 118 pairs of concepts 3 pairs of concepts had shortest paths containing three hyperlinks (on average 58.3 parallel paths between each pair of concepts), 78 pairs of concepts had shortest path containing two hyperlinks (on average 5.3 parallel paths between each pair of concepts) and 37 pairs of concepts had shortest paths containing one hyperlink (on average 1.0 parallel paths between each pair of concepts). The shortest paths are listed in alphabetical order so that possible parallel routes of the shortest paths between each pair of concepts are mentioned consecutively.

628 shortest routes between 118 pairs of concepts
<p><i>Shortest paths containing three hyperlinks:</i> entertainment->animation->light->earth; entertainment->ball->sphere->earth; entertainment->camping->cold->earth; entertainment->camping->electricity->earth; entertainment->camping->water->earth; entertainment->ceremony->battle->earth; entertainment->cooking->carbon->earth; entertainment->dance->rainforest->earth; entertainment->education->biology->earth; entertainment->employment->globalization->earth; entertainment->festival->season->earth; entertainment->film->sound->earth; entertainment->film->technology->earth; entertainment->leisure->time->earth; entertainment->literature->nature->earth; entertainment->monkey->human->earth; entertainment->music->biology->earth; entertainment->music->globalization->earth; entertainment->music->physics->earth; entertainment->music->sound->earth; entertainment->music->time->earth; entertainment->novel->globalization->earth; entertainment->poetry->globalization->earth; entertainment->radio->atom->earth; entertainment->radio->horizon->earth; entertainment->radio->light->earth; entertainment->radio->technology->earth; entertainment->rhythm->time->earth; entertainment->running->oxygen->earth; entertainment->running->speed->earth; entertainment->singing->human->earth; entertainment->stadium->steel->earth; entertainment->television->angle->earth; entertainment->writer->astronomy->earth; entertainment->writer->biology->earth; entertainment->writer->physics->earth; entertainment->zoo->extinction->earth; infrastructure->bridge->river->mammal; infrastructure->bus->camel->mammal; infrastructure->climate change->fish->mammal; infrastructure->coal->iron->mammal; infrastructure->communication->human->mammal; infrastructure->communication->sound->mammal; infrastructure->earthquake->earth->mammal; infrastructure->economy->iron->mammal; infrastructure->electricity->earth->mammal; infrastructure->electricity->muscle->mammal; infrastructure->electricity->shark->mammal; infrastructure->government->fear->mammal; infrastructure->museum->animal->mammal; infrastructure->museum->zoo->mammal; infrastructure->noise->sound->mammal; infrastructure->organization->human->mammal; infrastructure->road->river->mammal; infrastructure->storm->desert->mammal; infrastructure->storm->earth->mammal; infrastructure->storm->rainforest->mammal; infrastructure->sustainability->climate->mammal; infrastructure->sustainability->earth->mammal; infrastructure->sustainability->meat->mammal; infrastructure->sustainability->river->mammal; infrastructure->telephone->sound->mammal; infrastructure->trail->horse->mammal; infrastructure->transport->cattle->mammal; infrastructure->transport->horse->mammal; infrastructure->transport->human->mammal; infrastructure->transport->river->mammal; infrastructure->water->acid->mammal; infrastructure->water->climate->mammal; infrastructure->water->desert->mammal; infrastructure->water->earth->mammal; infrastructure->water->fish->mammal; infrastructure->water->human->mammal; infrastructure->water->life->mammal; infrastructure->water->river->mammal; infrastructure->water->whale->mammal; infrastructure->weapon->horse->mammal; infrastructure->weapon->hunting->mammal; infrastructure->vehicle->camel->mammal; infrastructure->wheel->cattle->mammal; infrastructure->wheel->horse->mammal; infrastructure->wheel->iron->mammal; mind->adaptation->climate->carbon dioxide; mind->art->globalization->carbon dioxide; mind->art->pollution->carbon dioxide; mind->awareness->animal->carbon dioxide; mind->biology->agriculture->carbon dioxide; mind->biology->animal->carbon dioxide; mind->biology->bacteria->carbon dioxide; mind->biology->climate->carbon dioxide; mind->biology->earth->carbon dioxide; mind->biology->ecology->carbon dioxide; mind->biology->energy->carbon dioxide; mind->biology->plant->carbon dioxide; mind->body->insect->carbon dioxide; mind->body->meat->carbon dioxide; mind->brain->alcohol->carbon dioxide; mind->brain->insect->carbon dioxide; mind->communication->bacteria->carbon dioxide; mind->communication->plant->carbon dioxide; mind->computer->washing machine->carbon dioxide; mind->conscience->animal->carbon dioxide; mind->conscience->carbon footprint->carbon dioxide; mind->conscience->earth->carbon dioxide; mind->conscience->ecology->carbon dioxide; mind->economics->globalization->carbon dioxide; mind->economics->pollution->carbon dioxide; mind->engineering->chemistry->carbon dioxide; mind->engineering->energy->carbon dioxide; mind->evolution->ant->carbon dioxide; mind->evolution->atmosphere->carbon dioxide; mind->evolution->bacteria->carbon dioxide; mind->evolution->crocodile->carbon dioxide; mind->evolution->earth->carbon dioxide; mind->evolution->ecology->carbon dioxide; mind->evolution->global warming->carbon dioxide; mind->evolution->insect->carbon dioxide; mind->evolution->oxygen->carbon dioxide; mind->evolution->plant->carbon dioxide; mind->evolution->virus->carbon dioxide; mind->family->animal->carbon dioxide; mind->fear->water->carbon dioxide; mind->gene->bacteria->carbon dioxide; mind->gene->virus->carbon dioxide; mind->human->agriculture->carbon dioxide; mind->human->earth->carbon dioxide; mind->human->global warming->carbon dioxide; mind->human->globalization->carbon dioxide; mind->human->pollution->carbon dioxide; mind->human->transport->carbon dioxide; mind->idea->fish->carbon</p>

dioxide; mind->language->globalization->carbon dioxide; mind->learning->energy->carbon dioxide; mind->life->animal->carbon dioxide; mind->life->bacteria->carbon dioxide; mind->life->carbon->carbon dioxide; mind->life->coal->carbon dioxide; mind->life->earth->carbon dioxide; mind->life->ecology->carbon dioxide; mind->life->fish->carbon dioxide; mind->life->insect->carbon dioxide; mind->life->oxygen->carbon dioxide; mind->life->plant->carbon dioxide; mind->life->virus->carbon dioxide; mind->machine->energy->carbon dioxide; mind->machine->engine->carbon dioxide; mind->machine->fuel->carbon dioxide; mind->materialism->energy->carbon dioxide; mind->matter->atom->carbon dioxide; mind->matter->chemistry->carbon dioxide; mind->matter->earth->carbon dioxide; mind->matter->energy->carbon dioxide; mind->matter->gas->carbon dioxide; mind->matter->liquid->carbon dioxide; mind->matter->water->carbon dioxide; mind->perception->ecology->carbon dioxide; mind->pie->bread->carbon dioxide; mind->pie->flour->carbon dioxide; mind->pie->sea->carbon dioxide; mind->psychology->chemistry->carbon dioxide; mind->reality->energy->carbon dioxide; mind->science->chemistry->carbon dioxide; mind->science->energy->carbon dioxide; mind->skull->animal->carbon dioxide; mind->spirit->blood->carbon dioxide; mind->taste->acid->carbon dioxide; mind->taste->alcohol->carbon dioxide; mind->taste->beer->carbon dioxide; mind->taste->blood->carbon dioxide; mind->taste->meat->carbon dioxide; mind->taste->soft drink->carbon dioxide; mind->taste->wine->carbon dioxide; mind->tool->agriculture->carbon dioxide; mind->tool->animal->carbon dioxide; mind->tool->truck->carbon dioxide

Shortest paths containing two hyperlinks:
entertainment->dance->animal; entertainment->public transport->carbon dioxide; entertainment->monkey->human; entertainment->singing->human; entertainment->gambing->law; entertainment->literature->law; entertainment->zoo->mammal; entertainment->education->philosophy; entertainment->literature->philosophy; entertainment->writer->philosophy; entertainment->cooking->protein; entertainment->artificial intelligence->psychology; entertainment->clown->psychology; entertainment->education->psychology; entertainment->game->psychology; entertainment->imagination->psychology; entertainment->insight->psychology; entertainment->music->psychology; entertainment->novel->psychology; entertainment->festival->religion; entertainment->literature->religion; entertainment->writer->religion; entertainment->education->science; entertainment->joke->science; entertainment->camping->water; food->acid->carbon dioxide; food->agriculture->carbon dioxide; food->animal->carbon dioxide; food->bacteria->carbon dioxide; food->blood->carbon dioxide; food->bread->carbon dioxide; food->ecology->carbon dioxide; food->energy->carbon dioxide; food->fish->carbon dioxide; food->fuel->carbon dioxide; food->kidney->carbon dioxide; food->meat->carbon dioxide; food->plant->carbon dioxide; food->potato->carbon dioxide; food->rice->carbon dioxide; food->virus->carbon dioxide; food->bacteria->earth; food->evolution->earth; food->fuel->earth; food->human->earth; food->sustainability->earth; food->famine->law; food->human->law; food->sustainability->law; food->acid->mammal; food->animal->mammal; food->butter->mammal; food->evolution->mammal; food->fish->mammal; food->human->mammal; food->immune system->mammal; food->kidney->mammal; food->meat->mammal; food->milk->mammal; food->muscle->mammal; food->seed->mammal; food->human->philosophy; food->human->psychology; food->evolution->religion; food->human->religion; food->ecology->science; food->human->science; food->sustainability->science; food->blood->water; food->bread->water; food->energy->water; food->fruit->water; food->honey->water; food->kidney->water; food->milk->water; food->plant->water; food->salt->water; food->soup->water; food->steam->water; food->sugar->water; food->sustainability->water; food->vinegar->water; food->vitamin->water; globalization->habitat->animal; globalization->life->animal; globalization->nature->animal; globalization->tiger->animal; globalization->communication->human; globalization->community->human; globalization->culture->human; globalization->earth->human; globalization->health->human; globalization->nature->human; globalization->transport->human; globalization->wealth->human; globalization->crime->law; globalization->democracy->law; globalization->economist->law; globalization->famine->law; globalization->liberty->law; globalization->philosophy->law; globalization->religion->law; globalization->sustainability->law; globalization->tax->law; globalization->earth->mammal; globalization->life->mammal; globalization->nature->mammal; globalization->river->mammal; globalization->tiger->mammal; globalization->carbon dioxide->protein; globalization->life->protein; globalization->crime->psychology; globalization->culture->psychology; globalization->health->psychology; globalization->philosophy->psychology; globalization->economics->science; globalization->knowledge->science; globalization->life->science; globalization->nature->science; globalization->religion->science; globalization->sustainability->science; globalization->technology->science; globalization->carbon dioxide->water; globalization->global warming->water; globalization->health->water; globalization->river->water; globalization->sustainability->water; globalization->tiger->water; globalization->transport->water; human->digestion->animal; human->family->animal; human->female->animal; human->genetics->animal; human->reproduction->animal; human->species->animal; human->tool->animal; human->agriculture->carbon dioxide; human->earth->carbon dioxide; human->global warming->carbon dioxide; human->globalization->carbon dioxide; human->pollution->carbon dioxide; human->transport->carbon dioxide; human->cooking->protein; human->digestion->protein; human->evolution->protein; human->gene->protein; human->genetics->protein; human->hunting->protein; human->mammal->protein; human->competition->water; human->fire->water; human->global warming->water; human->health->water; human->motivation->water; human->space->water; human->transport->water; infrastructure->museum->animal; infrastructure->coal->carbon dioxide; infrastructure->energy->carbon dioxide; infrastructure->public transport->carbon dioxide; infrastructure->storm->carbon dioxide; infrastructure->transport->carbon dioxide; infrastructure->water->carbon dioxide; infrastructure->earthquake->earth; infrastructure->electricity->earth; infrastructure->storm->earth; infrastructure->sustainability->earth; infrastructure->water->earth; infrastructure->communication->human; infrastructure->organization->human; infrastructure->transport->human; infrastructure->water->human; infrastructure->college->law; infrastructure->institution->law; infrastructure->ownership->law; infrastructure->police->law; infrastructure->road->law; infrastructure->sustainability->law; infrastructure->government->philosophy; infrastructure->museum->philosophy; infrastructure->energy->protein; infrastructure->water->protein; infrastructure->organization->psychology; infrastructure->city->religion; infrastructure->institution->religion; infrastructure->society->religion; infrastructure->university->religion; infrastructure->government->science; infrastructure->museum->science; infrastructure->primary school->science; infrastructure->secondary school->science; infrastructure->sustainability->science; infrastructure->university->science; mind->awareness->animal; mind->biology->animal; mind->conscience->animal; mind->family->animal; mind->life->animal; mind->skull->animal; mind->tool->animal; mind->biology->earth; mind->conscience->earth; mind->evolution->earth; mind->human->earth; mind->life->earth; mind->matter->earth; mind->emotion->law; mind->human->law; mind->philosophy->law; mind->reason->law; mind->religion->law; mind->spirit->law; mind->emotion->mammal; mind->evolution->mammal; mind->fear->mammal; mind->human->mammal; mind->intelligence->mammal; mind->learning->mammal; mind->life->mammal; mind->love->mammal; mind->skull->mammal; mind->biology->protein; mind->evolution->protein; mind->gene->protein; mind->life->protein; mind->fear->water; mind->matter->water; nature->animal->carbon dioxide; nature->atmosphere->carbon dioxide; nature->bacteria->carbon dioxide; nature->earth->carbon dioxide; nature->energy->carbon dioxide; nature->fish->carbon dioxide; nature->gas->carbon dioxide; nature->ice->carbon dioxide; nature->liquid->carbon dioxide; nature->oxygen->carbon dioxide; nature->planet->carbon dioxide; nature->plant->carbon dioxide; nature->pollution->carbon dioxide; nature->sea->carbon dioxide; nature->sun->carbon dioxide; nature->volcano->carbon dioxide; nature->civilization->law; nature->human->law; nature->wilderness->law; nature->art->philosophy; nature->consciousness->philosophy; nature->extinction->philosophy; nature->human->philosophy; nature->life->philosophy; nature->materialism->philosophy; nature->mind->philosophy; nature-

<p>>phenomenon->philosophy; nature->physics->philosophy; nature->science->philosophy; nature->animal->protein; nature->bacteria->protein; nature->biology->protein; nature->bone->protein; nature->digestion->protein; nature->dinosaur->protein; nature->dna->protein; nature->energy->protein; nature->evolution->protein; nature->fishing->protein; nature->genetics->protein; nature->hunting->protein; nature->life->protein; nature->mammal->protein; nature->muscle->protein; nature->oxygen->protein; nature->temperature->protein; nature->biology->psychology; nature->consciousness->psychology; nature->human->psychology; nature->laboratory->psychology; nature->mind->psychology; nature->science->psychology; nature->civilization->religion; nature->evolution->religion; nature->human->religion; nature->life->religion; nature->mind->religion; nature->planet->religion; nature->science->religion; nature->cloud->water; nature->energy->water; nature->extinction->water; nature->fishing->water; nature->ice->water; nature->liquid->water; nature->matter->water; nature->ocean->water; nature->oxygen->water; nature->physics->water; nature->planet->water; nature->plant->water; nature->river->water; nature->steam->water; nutrition->blood->animal; nutrition->digestion->animal; nutrition->dna->animal; nutrition->food->animal; nutrition->fruit->animal; nutrition->genetics->animal; nutrition->immune system->animal; nutrition->leaf->animal; nutrition->life->animal; nutrition->seed->animal; nutrition->agriculture->carbon dioxide; nutrition->atmosphere->carbon dioxide; nutrition->blood->carbon dioxide; nutrition->bread->carbon dioxide; nutrition->carbon->carbon dioxide; nutrition->energy->carbon dioxide; nutrition->iron->carbon dioxide; nutrition->leaf->carbon dioxide; nutrition->meat->carbon dioxide; nutrition->oxygen->carbon dioxide; nutrition->potato->carbon dioxide; nutrition->rice->carbon dioxide; nutrition->water->carbon dioxide; nutrition->wine->carbon dioxide; nutrition->atmosphere->earth; nutrition->carbon->earth; nutrition->dna->earth; nutrition->human->earth; nutrition->iron->earth; nutrition->life->earth; nutrition->oxygen->earth; nutrition->soil->earth; nutrition->sunlight->earth; nutrition->technology->earth; nutrition->water->earth; nutrition->butter->mammal; nutrition->digestion->mammal; nutrition->human->mammal; nutrition->immune system->mammal; nutrition->iron->mammal; nutrition->life->mammal; nutrition->meat->mammal; nutrition->milk->mammal; nutrition->seed->mammal; nutrition->experiment->philosophy; nutrition->human->philosophy; nutrition->life->philosophy; nutrition->psychology->philosophy; nutrition->science->philosophy; nutrition->herb->religion; nutrition->human->religion; nutrition->life->religion; nutrition->science->religion; transport->cattle->animal; transport->horse->animal; transport->landing->animal; transport->ocean->animal; transport->team->animal; transport->globalization->earth; transport->human->earth; transport->ocean->earth; transport->soil->earth; transport->steel->earth; transport->technology->earth; transport->water->earth; transport->human->law; transport->road->law; transport->tax->law; transport->cattle->mammal; transport->horse->mammal; transport->human->mammal; transport->river->mammal; transport->education->philosophy; transport->globalization->philosophy; transport->government->philosophy; transport->human->philosophy; transport->beer->protein; transport->carbon dioxide->protein; transport->water->protein; transport->wool->protein; transport->education->psychology; transport->human->psychology; transport->city->religion; transport->globalization->religion; transport->human->religion; transport->education->science; transport->government->science; transport->human->science; transport->technology->science; water->biology->animal; water->dna->animal; water->fish->animal; water->life->animal; water->whale->animal; water->human->law; water->politics->law; water->acid->mammal; water->climate->mammal; water->desert->mammal; water->earth->mammal; water->fish->mammal; water->human->mammal; water->life->mammal; water->river->mammal; water->whale->mammal; water->human->philosophy; water->life->philosophy; water->biology->psychology; water->human->psychology; water->human->religion; water->life->religion; water->human->science; water->life->science; water->politics->science</p> <p><i>Shortest paths containing one hyperlink:</i> food->animal; food->human; food->protein; globalization->carbon dioxide; globalization->carbon dioxide; globalization->earth; globalization->philosophy; globalization->religion; human->bikini; human->earth; human->law; human->mammal; human->philosophy; human->religion; human->science; infrastructure->water; mind->bikini; mind->human; mind->philosophy; mind->religion; mind->science; nature->animal; nature->earth; nature->human; nature->mammal; nature->science; nutrition->bikini; nutrition->human; nutrition->protein; nutrition->science; nutrition->water; transport->carbon dioxide; transport->human; transport->water; water->carbon dioxide; water->earth; water->human; water->protein</p>

This second listing below shows among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts. This listing contains all occurrence levels of hyperlinks whereas Table 11.10 was limited to shown only those hypelinks that had at least 5 occurrences.

Most occurring hyperlinks among 1393 hyperlinks between 118 pairs of concepts
Hyperlinks having 15 occurrences: mind->life
Hyperlinks having 14 occurrences: infrastructure->water; mind->evolution
Hyperlinks having 13 occurrences: (no hyperlinks having 13 occurrences)
Hyperlinks having 12 occurrences: energy->carbon dioxide
Hyperlinks having 11 occurrences: human->mammal; mind->biology; transport->human
Hyperlinks having 10 occurrences: mind->human
Hyperlinks having 9 occurrences: animal->carbon dioxide; globalization->carbon dioxide; human->earth; mind->matter; water->human
Hyperlinks having 8 occurrences: earth->carbon dioxide; food->human; globalization->earth; river->mammal
Hyperlinks having 7 occurrences: bacteria->carbon dioxide; earth->mammal; human->law; infrastructure->sustainability; mind->taste; water->earth
Hyperlinks having 6 occurrences: agriculture->carbon dioxide; ecology->carbon dioxide; entertainment->music; human->philosophy; human->religion; infrastructure->transport; mind->conscience; nature->human; nutrition->human; plant->carbon dioxide; water->life;
Hyperlinks having 5 occurrences: biology->earth; entertainment->writer; horse->mammal; infrastructure->museum; infrastructure->storm; life->animal; life->mammal; nature->science; nutrition->life; pollution->carbon dioxide; transport->carbon dioxide;

<p>transport->water; water->carbon dioxide;</p> <p><i>Hyperlinks having 4 occurrences:</i></p> <p>blood->carbon dioxide; chemistry->carbon dioxide; entertainment->camping; entertainment->education; entertainment->literature; entertainment->radio; fish->carbon dioxide; fish->mammal; food->animal; food->sustainability; globalization->life; globalization->nature; globalization->philosophy; globalization->religion; human->psychology; human->science; infrastructure->electricity; insect->carbon dioxide; iron->mammal; meat->carbon dioxide; mind->tool; nature->animal; oxygen->carbon dioxide; technology->earth; virus->carbon dioxide;</p>
<p><i>Hyperlinks having 3 occurrences:</i></p> <p>acid->mammal; atmosphere->carbon dioxide; biology->animal; bread->carbon dioxide; cattle->mammal; climate->mammal; communication->human; desert->mammal; electricity->earth; evolution->earth; evolution->protein; family->animal; food->evolution; food->kidney; global warming->carbon dioxide; globalization->health; globalization->sustainability; globalization->tiger; human->global warming; human->transport; infrastructure->communication; infrastructure->government; infrastructure->organization; infrastructure->wheel; life->earth; life->philosophy; life->protein; life->religion; matter->water; meat->mammal; mind->fear; mind->gene; mind->machine; mind->philosophy; mind->pie; mind->religion; mind->science; mind->skull; nature->earth; nature->energy; nature->life; nature->mammal; nature->mind; nature->oxygen; nature->planet; nutrition->iron; nutrition->science; nutrition->water; sound->mammal; sustainability->earth; sustainability->law; sustainability->science; time->earth; tool->animal; transport->cattle; transport->education; transport->globalization; transport->horse; water->fish; water->protein; water->whale;</p>
<p><i>Hyperlinks having 2 occurrences:</i></p> <p>acid->carbon dioxide; alcohol->carbon dioxide; animal->mammal; awareness->animal; biology->protein; biology->psychology; butter->mammal; camel->mammal; camping->water; carbon->carbon dioxide; carbon->earth; carbon dioxide->protein; city->religion; climate->carbon dioxide; coal->carbon dioxide; conscience->animal; conscience->earth; cooking->protein; digestion->animal; digestion->protein; dna->animal; earthquake->earth; education->philosophy; education->psychology; education->science; energy->protein; energy->water; entertainment->cooking; entertainment->dance; entertainment->festival; entertainment->film; entertainment->monkey; entertainment->novel; entertainment->running; entertainment->singing; entertainment->zoo; evolution->mammal; evolution->religion; famine->law; fear->mammal; fear->water; food->acid; food->bacteria; food->blood; food->bread; food->ecology; food->energy; food->fish; food->fuel; food->meat; food->milk; food->plant; fuel->carbon dioxide; gas->carbon dioxide; gene->protein; genetics->animal; genetics->protein; global warming->water; globalization->crime; globalization->culture; globalization->river; globalization->transport; government->philosophy; government->science; health->water; human->agriculture; human->digestion; human->genetics; human->globalization; human->pollution; hunting->protein; immune system->mammal; infrastructure->coal; infrastructure->earthquake; infrastructure->energy; infrastructure->institution; infrastructure->road; infrastructure->university; infrastructure->weapon; life->science; light->earth; liquid->carbon dioxide; mammal->protein; matter->earth; milk->mammal; mind->art; mind->awareness; mind->body; mind->brain; mind->communication; mind->economics; mind->emotion; mind->engineering; mind->family; mind->learning; mind->psychology; mind->spirit; monkey->human; muscle->mammal; museum->animal; nature->bacteria; nature->biology; nature->civilization; nature->consciousness; nature->evolution; nature->extinction; nature->fishing; nature->ice; nature->liquid; nature->physics; nature->plant; nature->atmosphere; nutrition->blood; nutrition->carbon; nutrition->digestion; nutrition->dna; nutrition->immune system; nutrition->leaf; nutrition->meat; nutrition->oxygen; nutrition->seed; organization->human; oxygen->earth; philosophy->law; physics->earth; plant->water; potato->carbon dioxide; public transport->carbon dioxide; religion->law; rice->carbon dioxide; river->water; road->law; science->philosophy; science->religion; sea->carbon dioxide; seed->mammal; singing->human; skull->animal; soil->earth; sound->earth; steam->water; steel->earth; storm->earth; sustainability->water; tax->law; technology->science; transport->government; transport->ocean; transport->river; transport->technology; water->acid; water->biology; water->climate; water->desert; water->politics; water->river; whale->mammal; wine->carbon dioxide; zoo->mammal;</p>
<p><i>Hyperlinks having 1 occurrences:</i></p> <p>adaptation->climate; angle->earth; animal->protein; animation->light; ant->carbon dioxide; art->globalization; art->philosophy; art->pollution; artificial intelligence->psychology; astronomy->earth; atmosphere->earth; atom->carbon dioxide; atom->earth; bacteria->earth; bacteria->protein; ball->sphere; battle->earth; beer->carbon dioxide; beer->protein; biology->agriculture; biology->bacteria; biology->climate; biology->ecology; biology->energy; biology->plant; blood->animal; blood->water; body->insect; body->meat; bone->protein; brain->alcohol; brain->insect; bread->water; bridge->river; bus->camel; camping->cold; camping->electricity; carbon dioxide->water; carbon footprint->carbon dioxide; cattle->animal; ceremony->battle; civilization->law; civilization->religion; climate change->fish; cloud->water; clown->psychology; coal->iron; cold->earth; college->law; communication->bacteria; communication->plant; communication->sound; community->human; competition->water; computer->washing machine; conscience->carbon footprint; conscience->ecology; consciousness->philosophy; consciousness->psychology; cooking->carbon; crime->law; crime->psychology; crocodile->carbon dioxide; culture->human; culture->psychology; dance->animal; dance->rainforest; democracy->law; digestion->mammal; dinosaur->protein; dna->earth; dna->protein; earth->human; ecology->science; economics->globalization; economics->pollution; economics->science; economist->law; economy->iron; education->biology; electricity->muscle; electricity->shark; emotion->law; emotion->mammal; employment->globalization; engine->carbon dioxide; engineering->chemistry; engineering->energy; entertainment->animation; entertainment->artificial intelligence; entertainment->ball; entertainment->ceremony; entertainment->clown; entertainment->employment; entertainment->gambling; entertainment->game; entertainment->imagination; entertainment->insight; entertainment->joke; entertainment->leisure; entertainment->poetry; entertainment->public transport; entertainment->rhythm; entertainment->stadium; entertainment->television; evolution->ant; evolution->atmosphere; evolution->bacteria; evolution->crocodile; evolution->ecology; evolution->global warming; evolution->insect; evolution->oxygen; evolution->plant; evolution->virus; experiment->philosophy; extinction->earth; extinction->philosophy; extinction->water; female->animal; festival->religion; festival->season; film->sound; film->technology; fire->water; fish->animal; fishing->protein; fishing->water; flour->carbon dioxide; food->agriculture; food->butter; food->famine; food->fruit; food->honey; food->immune system; food->muscle; food->potato; food->protein; food->rice; food->salt; food->seed; food->soup; food->steam; food->sugar; food->vinegar; food->virus; food->vitamin; fruit->animal; fruit->water; fuel->earth; gambling->law; game->psychology; gene->bacteria; gene->virus; globalization->communication; globalization->community; globalization->democracy; globalization->economics; globalization->economist; globalization->famine; globalization->global warming; globalization->habitat; globalization->knowledge; globalization->liberty; globalization->tax; globalization->technology; globalization->wealth; government->fear; habitat->animal; health-</p>

>human; health->psychology; herb->religion; honey->water; horizon->earth; horse->animal; human->bikini; human->competition; human->cooking; human->evolution; human->family; human->female; human->fire; human->gene; human->health; human->hunting; human->motivation; human->reproduction; human->space; human->species; human->tool; hunting->mammal; ice->carbon dioxide; ice->water; idea->fish; imagination->psychology; immune system->animal; infrastructure->bridge; infrastructure->bus; infrastructure->city; infrastructure->climate change; infrastructure->college; infrastructure->economy; infrastructure->noise; infrastructure->ownership; infrastructure->police; infrastructure->primary school; infrastructure->public transport; infrastructure->secondary school; infrastructure->society; infrastructure->telephone; infrastructure->trail; infrastructure->vehicle; insight->psychology; institution->law; institution->religion; intelligence->mammal; iron->carbon dioxide; iron->earth; joke->science; kidney->carbon dioxide; kidney->mammal; kidney->water; knowledge->science; laboratory->psychology; landing->animal; language->globalization; leaf->animal; leaf->carbon dioxide; learning->energy; learning->mammal; leisure->time; liberty->law; life->bacteria; life->carbon; life->coal; life->ecology; life->fish; life->insect; life->oxygen; life->plant; life->virus; liquid->water; literature->law; literature->nature; literature->philosophy; literature->religion; love->mammal; machine->energy; machine->engine; machine->fuel; materialism->energy; materialism->philosophy; matter->atom; matter->chemistry; matter->energy; matter->gas; matter->liquid; milk->water; mind->adaptation; mind->bikini; mind->computer; mind->idea; mind->intelligence; mind->language; mind->love; mind->materialism; mind->perception; mind->reality; mind->reason; motivation->water; muscle->protein; museum->philosophy; museum->science; museum->zoo; music->biology; music->globalization; music->physics; music->psychology; music->sound; music->time; nature->art; nature->atmosphere; nature->bone; nature->cloud; nature->digestion; nature->dinosaur; nature->dna; nature->fish; nature->gas; nature->genetics; nature->hunting; nature->laboratory; nature->materialism; nature->matter; nature->muscle; nature->ocean; nature->phenomenon; nature->pollution; nature->river; nature->sea; nature->steam; nature->sun; nature->temperature; nature->wilderness; nature->volcano; noise->sound; novel->globalization; novel->psychology; nutrition->agriculture; nutrition->bikini; nutrition->bread; nutrition->butter; nutrition->energy; nutrition->experiment; nutrition->food; nutrition->fruit; nutrition->genetics; nutrition->herb; nutrition->milk; nutrition->potato; nutrition->protein; nutrition->psychology; nutrition->rice; nutrition->soil; nutrition->sunlight; nutrition->technology; nutrition->wine; ocean->animal; ocean->earth; ocean->water; organization->psychology; ownership->law; oxygen->protein; oxygen->water; perception->ecology; phenomenon->philosophy; philosophy->psychology; physics->philosophy; physics->water; pie->bread; pie->flour; pie->sea; planet->carbon dioxide; planet->religion; planet->water; poetry->globalization; police->law; politics->law; politics->science; primary school->science; psychology->chemistry; psychology->philosophy; radio->atom; radio->horizon; radio->light; radio->technology; rainforest->earth; rainforest->mammal; reality->energy; reason->law; religion->science; reproduction->animal; rhythm->time; road->river; running->oxygen; running->speed; salt->water; science->chemistry; science->energy; science->psychology; season->earth; secondary school->science; seed->animal; shark->mammal; skull->mammal; society->religion; soft drink->carbon dioxide; soup->water; space->water; species->animal; speed->earth; sphere->earth; spirit->blood; spirit->law; stadium->steel; storm->carbon dioxide; storm->desert; storm->rainforest; sugar->water; sun->carbon dioxide; sunlight->earth; sustainability->climate; sustainability->meat; sustainability->river; taste->acid; taste->alcohol; taste->beer; taste->blood; taste->meat; taste->soft drink; taste->wine; team->animal; telephone->sound; television->angle; temperature->protein; tiger->animal; tiger->mammal; tiger->water; tool->agriculture; tool->truck; trail->horse; transport->beer; transport->city; transport->landing; transport->road; transport->soil; transport->steel; transport->tax; transport->team; transport->wool; truck->carbon dioxide; university->religion; university->science; washing machine->carbon dioxide; water->dna; wealth->human; weapon->horse; weapon->hunting; vehicle->camel; whale->animal; wheel->cattle; wheel->horse; wheel->iron; wilderness->law; vinegar->water; vitamin->water; volcano->carbon dioxide; wool->protein; writer->astronomy; writer->biology; writer->philosophy; writer->physics; writer->religion; zoo->extinction;

Appendix T

After publication of the publication [P1] we carried out empirical experiments of collaborative concept map construction process in small groups containing persons having ages in range of 15-18 years and representing four collaborator roles of Competing Values Framework ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23-24)). Before introducing collaborative concept map construction process to the student, we identified for each student which of four major collaborator roles (shown in Table 4.3 (originally published as Table 2 in publication [P1])) he represents by a questionnaire that is shown here in this Appendix T. Without revealing in advance what is the purpose of the questionnaire we asked the student to fill in this competing values self-assessment questionnaire that is adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23-24)) and among the six sets of four questions corresponding to each four major collaborator roles the one which recieved highest number of points was selected as the role of the student for collaborative concept map construction process in small groups. In the questionnaire questions 1-6 concern having characteristics of innovator-broker role, then questions 7-12 producer-director role, next questions 13-18 coordinator-monitor role and finally then questions 19-24 facilitator-mentor role. We present here both English version and Finnish version of questionnaire that we used with students (Finnish version translated from English version by Lauri Lahti).

First name: _____ Last name: _____ Year of birth: _____

All these questions ask about how you work as a member in a group.

Please think about what is your role/position when working in a group of people.

For example, think about how you feel/ behave when you have to work in a student group at school or when you are doing something together with your friends.

Here you have 24 statements. Please answer how much you agree or disagree with each statement.

Select one number (1, 2, 3, 4 or 5) that corresponds to your opinion:

1 = "I strongly AGREE", 2="I quite much AGREE", 3="Neutral opinion",

4 ="I quite much DISAGREE", 5 = "I strongly DISAGREE"

"When I work as a member in a group..."



- | | | | | | |
|--|---|---|---|---|---|
| 1) ...I am flexible to tolerate changes. | 1 | 2 | 3 | 4 | 5 |
| 2) ...I am actively thinking creatively. | 1 | 2 | 3 | 4 | 5 |
| 3) ...I am active to create changes. | 1 | 2 | 3 | 4 | 5 |
| 4) ...I am active in building and keeping power structures in the group. | 1 | 2 | 3 | 4 | 5 |
| 5) ...I am active to negotiate (talk) to reach agreement and commitment. | 1 | 2 | 3 | 4 | 5 |
| 6) ...I am actively presenting (telling) new ideas to other people. | 1 | 2 | 3 | 4 | 5 |
| 7) ...I make big efforts to get people working productively. | 1 | 2 | 3 | 4 | 5 |
| 8) ...I actively try to make working environment productive. | 1 | 2 | 3 | 4 | 5 |
| 9) ...I am actively thinking how to use time well. | 1 | 2 | 3 | 4 | 5 |
| 10) ...I am actively planning and setting goals (targets). | 1 | 2 | 3 | 4 | 5 |
| 11) ...I am actively designing and organizing things. | 1 | 2 | 3 | 4 | 5 |
| 12) ...I am efficient in delegating (sharing) work to other people. | 1 | 2 | 3 | 4 | 5 |
| 13) ...I am actively thinking how people can best work together. | 1 | 2 | 3 | 4 | 5 |
| 14) ...I am actively designing how work should be done. | 1 | 2 | 3 | 4 | 5 |
| 15) ...I am actively thinking many different things that belong to current work. | 1 | 2 | 3 | 4 | 5 |
| 16) ...I am actively giving attention to my personal performance in group. | 1 | 2 | 3 | 4 | 5 |
| 17) ...I am actively giving attention to the performance of the whole group altogether. | 1 | 2 | 3 | 4 | 5 |
| 18) ...I am actively giving attention to the performance of each individual person in the group. | 1 | 2 | 3 | 4 | 5 |
| 19) ...I am actively building (forming) groups and teams. | 1 | 2 | 3 | 4 | 5 |
| 20) ...I actively want to make decisions so that all people in group can agree. | 1 | 2 | 3 | 4 | 5 |
| 21) ...I make big efforts to help people to avoid conflicts in group. | 1 | 2 | 3 | 4 | 5 |
| 22) ...I actively understand well myself and other people. | 1 | 2 | 3 | 4 | 5 |
| 23) ...I actively want to communicate effectively. | 1 | 2 | 3 | 4 | 5 |
| 24) ...I actively want to give guidance to other people. | 1 | 2 | 3 | 4 | 5 |

Finnish version of questionnaire:

Etunimi: _____ Sukunimi: _____ Syntymävuosi: _____

Kaikki nämä kysymykset käsittelevät sitä, miten sinä työskentelet ryhmän jäsenenä.

Ajattele, millainen rooli/asema sinulla on, kun työskentelet ihmisten muodostamassa ryhmässä.

Esimerkiksi ajattele, millaisia ovat tuntemuksesi/käyttäytymisesi, kun sinun täytyy työskennellä opiskelijaryhmässä koulussa tai kun olet tekemässä jotain yhdessä ystäväsi kanssa.

Tässä sinulla on 24 väittämää. Vastaa, kuinka paljon olet samaa tai eri mieltä kustakin väittämästä.

Valitse yksi numero (1, 2, 3, 4 tai 5), joka täsmää sinun mielipiteeseesi:

1 = "Olen vahvasti SAMAA mieltä", 2 = "Olen melko paljon SAMAA mieltä", 3 = "Neutraali mielipide", 4 = "Olen melko paljon ERI mieltä", 5 = "Olen vahvasti ERI mieltä"

"Kun työskentelet ryhmän jäsenenä, ..."

	☺	☹
1) ...olen joustava sietämään muutoksia.	1 2 3 4 5	
2) ...olen ahkera ajattelemaan luovasti.	1 2 3 4 5	
3) ...olen ahkera luomaan muutoksia.	1 2 3 4 5	
4) ...olen ahkera rakentamaan ja ylläpitämään valtarakenteita ryhmässä.	1 2 3 4 5	
5) ...olen ahkera neuvottelemaan (puhumaan), jotta yhteisymmärrys ja omistautuminen voitaisiin saavuttaa.	1 2 3 4 5	
6) ...olen ahkera esittelemään (kertomaan) uusia ajatuksia toisille ihmisille.	1 2 3 4 5	
7) ...teen suuria ponnisteluja, jotta saisin ihmiset työskentelemään tuottavasti.	1 2 3 4 5	
8) ...yrityn ahkerasti tehdä työskentely-ympäristöstä tuottavan.	1 2 3 4 5	
9) ...ajattelem ahkerasti, kuinka ajan voisi käyttää hyvin.	1 2 3 4 5	
10) ...olen ahkera laatimaan aikatauluja ja asettamaan tavoitteita (päämääriä).	1 2 3 4 5	
11) ...olen ahkera suunnittelemaan ja järjestämään asioita.	1 2 3 4 5	
12) ...olen ahkera välittämään (jakamaan) työtä toisille ihmisille.	1 2 3 4 5	
13) ...olen ahkera ajattelemaan, kuinka ihmiset voisivat parhaiten työskennellä yhdessä.	1 2 3 4 5	
14) ...olen ahkera suunnittelemaan, miten työ pitäisi tehdä.	1 2 3 4 5	
15) ...olen ahkera ajattelemaan useita eri asioita, jotka kuuluvat senhetkiseen työhön.	1 2 3 4 5	
16) ...olen ahkera kiinnittämään huomiota henkilökohtaiseen suoriutukseeni ryhmässä.	1 2 3 4 5	
17) ...olen ahkera kiinnittämään huomiota koko ryhmän suoriutukseen yhdessä.	1 2 3 4 5	
18) ...olen ahkera kiinnittämään huomiota jokaisen yksittäisen henkilön suoriutukseen ryhmässä.	1 2 3 4 5	
19) ...olen ahkera rakentamaan (muodostamaan) ryhmiä ja joukkueita.	1 2 3 4 5	
20) ...haluan ahkerasti tehdä ratkaisuja niin, että kaikki ihmiset ryhmässä voivat olla samaa mieltä.	1 2 3 4 5	
21) ...teen suuria ponnisteluja auttaakseni ihmisiä välttämään ristiriitoja ryhmässä.	1 2 3 4 5	
22) ...olen ahkera ymmärtämään hyvin itseäni ja muita ihmisiä.	1 2 3 4 5	
23) ...haluan ahkerasti viestiä tavalla, joka vaikuttaa.	1 2 3 4 5	
24) ...haluan ahkerasti antaa opastusta toisille ihmisille.	1 2 3 4 5	

Appendix U

This listing shows for 102 core concepts the highest-ranking hyperlinked concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks (as explained in Subchapter 6.3). Value of “position among hyperlinks departing from Wikipedia article of start concept” indicates for the highest-ranking start concept or end concept what is its ranking position among all start concepts (in natural order of increasing distance from the beginning of the article) of those hyperlinks that arrive to current end concept (N/A = not available).

Observed concept	Ranking based on hierarchy of hyperlinks for observed concept		Observed concept	Ranking based on hierarchy of hyperlinks for observed concept
Concept	End concepts for hyperlinks departing from observed concept (position among hyperlinks)		Concept	Start concepts for hyperlinks arriving to observed concept (position among hyperlinks)
Adolescence	Childhood (1)		Adolescence	Childhood (1)
Adolescence	Child (2)		Adolescence	Child (2)
Adolescence	Television (3)		Adolescence	Education (5)
Adolescence	Sport (4)		Adolescence	Infant (6)
Adolescence	Education (5)		Adolescence	Old_age (7)
Adolescence	Infant (6)		Adolescence	Human (N/A)
Adolescence	Old_age (7)		Adolescence	Dog (N/A)
Animal	Organism (1)		Adolescence	Friendship (N/A)
Animal	Plant (2)		Animal	Plant (2)
Animal	Human (3)		Animal	Human (3)
Animal	Water (4)		Animal	Nature (7)
Animal	Oxygen (5)		Animal	Atmosphere_of_Earth (9)
Animal	Evolution (6)		Animal	Biology (10)
Animal	Nature (7)		Animal	Food (N/A)
Animal	Time (8)		Animal	Birth (N/A)
Animal	Atmosphere_of_Earth (9)		Animal	Eating (N/A)
Animal	Biology (10)		Animal	Friendship (N/A)
Atmosphere_of_Earth	Oxygen (1)		Animal	Pet (N/A)
Atmosphere_of_Earth	Organism (2)		Atmosphere_of_Earth	Nature (5)
Atmosphere_of_Earth	Evolution (3)		Atmosphere_of_Earth	Biology (7)
Atmosphere_of_Earth	Automobile (4)		Atmosphere_of_Earth	Plant (8)
Atmosphere_of_Earth	Nature (5)		Atmosphere_of_Earth	Animal (9)
Atmosphere_of_Earth	Time (6)		Automobile	Oxygen (1)
Atmosphere_of_Earth	Biology (7)		Automobile	City (N/A)
Atmosphere_of_Earth	Plant (8)		Automobile	Atmosphere_of_Earth (N/A)
Atmosphere_of_Earth	Animal (9)		Bed	Dream (3)
Automobile	Oxygen (1)		Biology	Evolution (1)
Bed	Infant (1)		Biology	Organism (2)
Bed	Hospital (2)		Biology	Health (3)
Bed	Dream (3)		Biology	Plant (5)
Biology	Evolution (1)		Biology	Animal (6)
Biology	Organism (2)		Biology	Nature (7)
Biology	Health (3)		Biology	Atmosphere_of_Earth (9)
Biology	Human (4)		Biology	Education (N/A)
Biology	Plant (5)		Biology	Love (N/A)
Biology	Animal (6)		Biology	Old_age (N/A)
Biology	Nature (7)		Biology	Water (N/A)
Biology	Time (8)		Birth	Parent (N/A)
Biology	Atmosphere_of_Earth (9)		Book	Paper (1)
Birth	Animal (1)		Book	Hobby (N/A)
Birth	Mother (2)		Bread	Food (4)
Birth	Sun (3)		Cat	Dog (2)
Birth	Death (4)		Cat	Pet (3)
Book	Paper (1)		Child	Parent (1)
Book	Music (2)		Child	Childhood (2)
Bread	Water (1)		Child	Infant (3)
Bread	Paper (2)		Child	Old_age (4)
Bread	Money (3)		Child	Adolescence (5)
Bread	Food (4)		Child	Family (8)
Cat	Human (1)		Child	Education (N/A)
Cat	Dog (2)		Childhood	Child (1)
Cat	Pet (3)		Childhood	Infant (2)
Child	Parent (1)		Childhood	Old_age (3)
Child	Childhood (2)		Childhood	Adolescence (4)

Child	Infant (3)		Childhood	Human (N/A)
Child	Old_age (4)		Childhood	Education (N/A)
Child	Adolescence (5)		City	Human (N/A)
Child	Sibling (6)		Clock	Time (1)
Child	Marriage (7)		Clock	Future (3)
Child	Family (8)		Clothing	Paper (4)
Child	Leisure (9)		Clothing	Human (N/A)
Childhood	Child (1)		Clothing	Shoe (N/A)
Childhood	Infant (2)		Computer	Clock (N/A)
Childhood	Old_age (3)		Computer	Food (N/A)
Childhood	Adolescence (4)		Death	Disease (2)
City	Automobile (1)		Death	Diet_(nutrition) (6)
City	Rain (2)		Death	Future (N/A)
City	Religion (3)		Death	Food (N/A)
Clock	Time (1)		Death	Birth (N/A)
Clock	Computer (2)		Death	Marriage (N/A)
Clock	Future (3)		Death	Old_age (N/A)
Clothing	Religion (1)		Diet_(nutrition)	Health (2)
Clothing	Television (2)		Diet_(nutrition)	Death (3)
Clothing	Marriage (3)		Diet_(nutrition)	Food (N/A)
Clothing	Paper (4)		Diet_(nutrition)	Human (N/A)
Computer	Television (1)		Diet_(nutrition)	Physical_fitness (N/A)
Computer	Telephone (2)		Disease	Death (1)
Death	Organism (1)		Disease	Health (N/A)
Death	Disease (2)		Disease	Hospital (N/A)
Death	Evolution (3)		Disease	War (N/A)
Death	Heart (4)		Disease	Oxygen (N/A)
Death	Oxygen (5)		Dog	Pet (1)
Death	Diet_(nutrition) (6)		Dog	Cat (3)
Death	Physical_fitness (7)		Dream	Bed (2)
Death	Human (8)		Eating	Food (1)
Death	War (9)		Eating	Hobby (N/A)
Diet_(nutrition)	Organism (1)		Eating	Leisure (N/A)
Diet_(nutrition)	Health (2)		Education	Learning (1)
Diet_(nutrition)	Death (3)		Education	Adolescence (4)
Diet_(nutrition)	Religion (4)		Education	School (6)
Disease	Death (1)		Education	Teacher (9)
Dog	Pet (1)		Education	Leisure (13)
Dog	Adolescence (2)		Education	Time (N/A)
Dog	Cat (3)		Education	Test_(assessment) (N/A)
Dream	God (1)		Education	Hobby (N/A)
Dream	Bed (2)		Education	Peace (N/A)
Eating	Food (1)		Emotion	Sadness (3)
Eating	Animal (2)		Emotion	Happiness (5)
Eating	Organism (3)		Emotion	Love (6)
Eating	Plant (4)		Emotion	Hatred (7)
Eating	Human (5)		Emotion	Pleasure (8)
Education	Learning (1)		Emotion	Human (N/A)
Education	Philosophy (2)		Emotion	Marriage (N/A)
Education	Childhood (3)		Evolution	Biology (1)
Education	Adolescence (4)		Evolution	Organism (2)
Education	Child (5)		Evolution	Human (N/A)
Education	School (6)		Evolution	Nature (N/A)
Education	Human (7)		Evolution	Animal (N/A)
Education	Biology (8)		Evolution	Flower (N/A)
Education	Teacher (9)		Evolution	Future (N/A)
Education	Sibling (10)		Evolution	Religion (N/A)
Education	Marriage (11)		Evolution	Atmosphere_of_Earth (N/A)
Education	Family (12)		Evolution	Death (N/A)
Education	Leisure (13)		Evolution	Emotion (N/A)
Emotion	Experience (1)		Experience	Emotion (N/A)
Emotion	Evolution (2)		Experience	Learning (N/A)
Emotion	Sadness (3)		Experience	World (N/A)
Emotion	Joy (4)		Family	Marriage (1)
Emotion	Happiness (5)		Family	Mother (2)
Emotion	Love (6)		Family	Father (3)
Emotion	Hatred (7)		Family	Sibling (4)
Emotion	Pleasure (8)		Family	Child (5)
Evolution	Biology (1)		Family	Leisure (6)
Evolution	Organism (2)		Family	Human (N/A)
Evolution	Oxygen (3)		Family	Education (N/A)
Evolution	Plant (4)		Family	Love (N/A)
Evolution	Philosophy (5)		Family	Home (N/A)
Experience	Time (1)		Family	House (N/A)
Experience	Philosophy (2)		Family	Party (N/A)

Family	Marriage (1)		Father	Parent (1)
Family	Mother (2)		Father	Mother (2)
Family	Father (3)		Father	Family (4)
Family	Sibling (4)		Father	Sibling (5)
Family	Child (5)		Father	God (N/A)
Family	Leisure (6)		Flower	Plant (2)
Father	Parent (1)		Flower	Forest (N/A)
Father	Mother (2)		Food	Eating (1)
Father	Marriage (3)		Food	Bread (4)
Father	Family (4)		Food	Health (10)
Father	Sibling (5)		Food	Hobby (N/A)
Father	Love (6)		Food	Money (N/A)
Flower	Evolution (1)		Forest	Tree (1)
Flower	Plant (2)		Forest	Plant (4)
Food	Eating (1)		Friendship	Love (3)
Food	Animal (2)		Future	Time (1)
Food	Plant (3)		Future	Clock (7)
Food	Bread (4)		Goal	Purpose (1)
Food	Water (5)		Goal	Teacher (N/A)
Food	War (6)		God	Religion (1)
Food	School (7)		God	Philosophy (2)
Food	Computer (8)		God	Time (N/A)
Food	Diet (nutrition) (9)		God	Human (N/A)
Food	Health (10)		God	Dream (N/A)
Food	Death (11)		God	Marriage (N/A)
Food	Human (12)		God	Purpose (N/A)
Forest	Tree (1)		Happiness	Emotion (1)
Forest	Flower (2)		Happiness	Joy (2)
Forest	Rain (3)		Happiness	Human (N/A)
Forest	Plant (4)		Happiness	Pleasure (N/A)
Friendship	Philosophy (1)		Happiness	Purpose (N/A)
Friendship	Adolescence (2)		Happiness	Hatred (N/A)
Friendship	Love (3)		Happiness	Love (N/A)
Friendship	Animal (4)		Happiness	Sadness (N/A)
Future	Time (1)		Hatred	Emotion (1)
Future	Philosophy (2)		Hatred	Pleasure (2)
Future	Human (3)		Hatred	Love (4)
Future	Evolution (4)		Hatred	Sadness (5)
Future	Religion (5)		Hatred	War (N/A)
Future	Death (6)		Health	Physical_fitness (2)
Future	Clock (7)		Health	Diet (nutrition) (3)
Goal	Purpose (1)		Health	Food (4)
God	Religion (1)		Health	Biology (5)
God	Philosophy (2)		Health	Human (N/A)
God	Father (3)		Health	Infant (N/A)
God	Nature (4)		Health	Hospital (N/A)
Ground	Philosophy (1)		Heart	Oxygen (N/A)
Happiness	Emotion (1)		Heart	Death (N/A)
Happiness	Joy (2)		Heart	Organism (N/A)
Hatred	Emotion (1)		Home	House (2)
Hatred	Pleasure (2)		Hospital	Bed (N/A)
Hatred	Happiness (3)		Hospital	Infant (N/A)
Hatred	Love (4)		House	Home (2)
Hatred	Sadness (5)		House	Human (N/A)
Health	Disease (1)		House	Hobby (N/A)
Health	Physical_fitness (2)		Human	Animal (9)
Health	Diet (nutrition) (3)		Human	Religion (12)
Health	Food (4)		Human	World (N/A)
Health	Biology (5)		Human	People (N/A)
Hobby	Leisure (1)		Human	Nature (N/A)
Hobby	Sport (2)		Human	Food (N/A)
Hobby	Book (3)		Human	Biology (N/A)
Hobby	Education (4)		Human	Death (N/A)
Hobby	Food (5)		Human	Water (N/A)
Hobby	Eating (6)		Human	Eating (N/A)
Hobby	Plant (7)		Human	Future (N/A)
Hobby	House (8)		Human	Parent (N/A)
Home	Family (1)		Human	Mother (N/A)
Home	House (2)		Human	Education (N/A)
Home	Love (3)		Human	Cat (N/A)
Hospital	Disease (1)		Infant	Child (1)
Hospital	Health (2)		Infant	Old_age (4)
House	Family (1)		Infant	Childhood (5)
House	Home (2)		Infant	Adolescence (6)
House	Television (3)		Infant	Bed (N/A)

House	Pet (4)		Joy	Happiness (1)
Human	City (1)		Joy	Emotion (N/A)
Human	Diet (nutrition) (2)		Learning	Education (2)
Human	Childhood (3)		Learning	Teacher (N/A)
Human	Adolescence (4)		Leisure	Education (4)
Human	Old_age (5)		Leisure	Marriage (7)
Human	Emotion (6)		Leisure	Family (8)
Human	Love (7)		Leisure	Hobby (N/A)
Human	Evolution (8)		Leisure	Child (N/A)
Human	Animal (9)		Leisure	Mother (N/A)
Human	Family (10)		Light	Time (1)
Human	Philosophy (11)		Light	Plant (N/A)
Human	Religion (12)		Love	Emotion (2)
Human	Clothing (13)		Love	Pleasure (3)
Human	House (14)		Love	Hatred (5)
Human	Oxygen (15)		Love	Sadness (6)
Human	Happiness (16)		Love	Friendship (7)
Human	Health (17)		Love	Marriage (11)
Human	War (18)		Love	Human (N/A)
Human	God (19)		Love	Mother (N/A)
Human	Music (20)		Love	Father (N/A)
Infant	Child (1)		Love	Home (N/A)
Infant	Hospital (2)		Love	Sibling (N/A)
Infant	Health (3)		Marriage	Family (2)
Infant	Old_age (4)		Marriage	Love (3)
Infant	Childhood (5)		Marriage	Sibling (7)
Infant	Adolescence (6)		Marriage	Leisure (8)
Joy	Happiness (1)		Marriage	Child (N/A)
Learning	Experience (1)		Marriage	Education (N/A)
Learning	Education (2)		Marriage	Mother (N/A)
Learning	Time (3)		Marriage	Father (N/A)
Learning	Physical_fitness (4)		Marriage	Clothing (N/A)
Leisure	Time (1)		Money	Bread (N/A)
Leisure	Work (2)		Mother	Parent (1)
Leisure	Eating (3)		Mother	Father (3)
Leisure	Education (4)		Mother	Family (4)
Leisure	Television (5)		Mother	Sibling (5)
Leisure	Sibling (6)		Mother	Birth (N/A)
Leisure	Marriage (7)		Music	Human (N/A)
Leisure	Family (8)		Music	Book (N/A)
Light	Time (1)		Music	Pleasure (N/A)
Light	Sun (2)		Music	Party (N/A)
Light	Television (3)		Music	Philosophy (N/A)
Love	Family (1)		Music	Test (assessment) (N/A)
Love	Emotion (2)		Nature	Plant (5)
Love	Pleasure (3)		Nature	Animal (6)
Love	Happiness (4)		Nature	Biology (8)
Love	Hatred (5)		Nature	Atmosphere_of_Earth (10)
Love	Sadness (6)		Nature	God (N/A)
Love	Friendship (7)		Old_age	Infant (3)
Love	Philosophy (8)		Old_age	Child (4)
Love	Religion (9)		Old_age	Childhood (5)
Love	Biology (10)		Old_age	Adolescence (6)
Love	Marriage (11)		Old_age	Human (N/A)
Marriage	Religion (1)		Organism	Biology (1)
Marriage	Family (2)		Organism	Evolution (2)
Marriage	Love (3)		Organism	Plant (4)
Marriage	God (4)		Organism	Animal (N/A)
Marriage	Emotion (5)		Organism	Atmosphere_of_Earth (N/A)
Marriage	Death (6)		Organism	Nature (N/A)
Marriage	Sibling (7)		Organism	Death (N/A)
Marriage	Leisure (8)		Organism	Diet (nutrition) (N/A)
Money	Water (1)		Organism	Eating (N/A)
Money	Food (2)		Organism	Water (N/A)
Mother	Parent (1)		Oxygen	Plant (1)
Mother	Human (2)		Oxygen	Automobile (2)
Mother	Father (3)		Oxygen	Sun (3)
Mother	Family (4)		Oxygen	Water (9)
Mother	Sibling (5)		Oxygen	Atmosphere_of_Earth (N/A)
Mother	Marriage (6)		Oxygen	Nature (N/A)
Mother	Love (7)		Oxygen	Animal (N/A)
Mother	Leisure (8)		Oxygen	Evolution (N/A)
Music	Religion (1)		Oxygen	Human (N/A)
Music	Time (2)		Oxygen	Death (N/A)
Music	Television (3)		Oxygen	Tree (N/A)

Nature	Human (1)		Paper	Book (1)
Nature	Sun (2)		Paper	Clothing (2)
Nature	Oxygen (3)		Paper	Pen (N/A)
Nature	Organism (4)		Paper	Bread (N/A)
Nature	Plant (5)		Parent	Father (1)
Nature	Animal (6)		Parent	Mother (2)
Nature	Evolution (7)		Parent	Child (5)
Nature	Biology (8)		Parent	Sibling (6)
Nature	Time (9)		Peace	War (2)
Nature	Atmosphere_of_Earth (10)		People	Pet (N/A)
Old_age	Biology (1)		Pet	Dog (2)
Old_age	Death (2)		Pet	Cat (3)
Old_age	Infant (3)		Pet	House (N/A)
Old_age	Child (4)		Philosophy	Religion (1)
Old_age	Childhood (5)		Philosophy	God (2)
Old_age	Adolescence (6)		Philosophy	Human (N/A)
Organism	Biology (1)		Philosophy	Experience (N/A)
Organism	Evolution (2)		Philosophy	Time (N/A)
Organism	Heart (3)		Philosophy	People (N/A)
Organism	Plant (4)		Philosophy	Education (N/A)
Oxygen	Plant (1)		Philosophy	Future (N/A)
Oxygen	Automobile (2)		Philosophy	Love (N/A)
Oxygen	Sun (3)		Philosophy	Friendship (N/A)
Oxygen	Philosophy (4)		Philosophy	Ground (N/A)
Oxygen	Heart (5)		Philosophy	Pleasure (N/A)
Oxygen	Disease (6)		Philosophy	Purpose (N/A)
Oxygen	Sport (7)		Philosophy	Evolution (N/A)
Oxygen	Rain (8)		Philosophy	Oxygen (N/A)
Oxygen	Water (9)		Philosophy	Test_(assessment) (N/A)
Paper	Book (1)		Physical_fitness	Health (1)
Paper	Clothing (2)		Physical_fitness	Death (N/A)
Parent	Father (1)		Physical_fitness	Learning (N/A)
Parent	Mother (2)		Plant	Organism (1)
Parent	Birth (3)		Plant	Animal (3)
Parent	Human (4)		Plant	Water (5)
Parent	Child (5)		Plant	Oxygen (6)
Parent	Sibling (6)		Plant	Forest (7)
Party	Music (1)		Plant	Flower (8)
Party	Television (2)		Plant	Nature (9)
Party	Family (3)		Plant	Atmosphere_of_Earth (11)
Peace	Education (1)		Plant	Biology (12)
Peace	War (2)		Plant	Food (N/A)
Pen	Paper (1)		Plant	Evolution (N/A)
People	Human (1)		Plant	Eating (N/A)
People	Philosophy (2)		Plant	Hobby (N/A)
People	Religion (3)		Plant	Rain (N/A)
People	Purpose (4)		Plant	Summer (N/A)
Pet	Animal (1)		Plant	Sun (N/A)
Pet	Dog (2)		Pleasure	Emotion (1)
Pet	Cat (3)		Pleasure	Hatred (3)
Pet	People (4)		Pleasure	Love (4)
Philosophy	Religion (1)		Pleasure	Sadness (5)
Philosophy	God (2)		Purpose	Goal (1)
Philosophy	Music (3)		Purpose	People (N/A)
Physical_fitness	Health (1)		Rain	Water (1)
Physical_fitness	Diet_(nutrition) (2)		Rain	City (N/A)
Plant	Organism (1)		Rain	Forest (N/A)
Plant	Tree (2)		Rain	Oxygen (N/A)
Plant	Animal (3)		Religion	Philosophy (1)
Plant	Light (4)		Religion	God (2)
Plant	Water (5)		Religion	Human (5)
Plant	Oxygen (6)		Religion	People (N/A)
Plant	Forest (7)		Religion	War (N/A)
Plant	Flower (8)		Religion	Future (N/A)
Plant	Nature (9)		Religion	Time (N/A)
Plant	Time (10)		Religion	City (N/A)
Plant	Atmosphere_of_Earth (11)		Religion	Clothing (N/A)
Plant	Biology (12)		Religion	Diet_(nutrition) (N/A)
Pleasure	Emotion (1)		Religion	Love (N/A)
Pleasure	Happiness (2)		Religion	Marriage (N/A)
Pleasure	Hatred (3)		Religion	Music (N/A)
Pleasure	Love (4)		Sadness	Emotion (1)
Pleasure	Sadness (5)		Sadness	Pleasure (2)
Pleasure	Music (6)		Sadness	Hatred (4)
Pleasure	Philosophy (7)		Sadness	Love (5)

Purpose	Goal (1)		Sadness	Sorrow (6)
Purpose	Philosophy (2)		School	Teacher (1)
Purpose	God (3)		School	Education (2)
Purpose	Happiness (4)		School	Food (N/A)
Rain	Water (1)		Sea	Water (1)
Rain	Plant (2)		Sibling	Parent (1)
Rain	Sun (3)		Sibling	Family (3)
Religion	Philosophy (1)		Sibling	Mother (4)
Religion	God (2)		Sibling	Father (5)
Religion	Sun (3)		Sibling	Marriage (6)
Religion	Evolution (4)		Sibling	Child (N/A)
Religion	Human (5)		Sibling	Education (N/A)
Sadness	Emotion (1)		Sibling	Leisure (N/A)
Sadness	Pleasure (2)		Sorrow	Sadness (1)
Sadness	Happiness (3)		Sport	Adolescence (N/A)
Sadness	Hatred (4)		Sport	Hobby (N/A)
Sadness	Love (5)		Sport	Oxygen (N/A)
Sadness	Sorrow (6)		Sun	Oxygen (1)
School	Teacher (1)		Sun	Light (N/A)
School	Education (2)		Sun	Water (N/A)
Sea	Water (1)		Sun	Nature (N/A)
Shoe	Clothing (1)		Sun	Birth (N/A)
Sibling	Parent (1)		Sun	Rain (N/A)
Sibling	Love (2)		Sun	Religion (N/A)
Sibling	Family (3)		Teacher	Education (1)
Sibling	Mother (4)		Teacher	School (2)
Sibling	Father (5)		Teacher	Test_(assessment) (N/A)
Sibling	Marriage (6)		Telephone	Computer (N/A)
Sorrow	Sadness (1)		Television	Time (N/A)
Sport	Television (1)		Television	Music (N/A)
Summer	Plant (1)		Television	Adolescence (N/A)
Sun	Oxygen (1)		Television	Clothing (N/A)
Sun	Plant (2)		Television	Computer (N/A)
Teacher	Education (1)		Television	House (N/A)
Teacher	School (2)		Television	Leisure (N/A)
Teacher	Goal (3)		Television	Light (N/A)
Teacher	Learning (4)		Television	Party (N/A)
Test_(assessment)	Education (1)		Television	Sport (N/A)
Test_(assessment)	Philosophy (2)		Time	Clock (3)
Test_(assessment)	Music (3)		Time	Future (5)
Test_(assessment)	Teacher (4)		Time	Light (6)
Time	Religion (1)		Time	Experience (N/A)
Time	Philosophy (2)		Time	Nature (N/A)
Time	Clock (3)		Time	Plant (N/A)
Time	God (4)		Time	Water (N/A)
Time	Future (5)		Time	Animal (N/A)
Time	Light (6)		Time	Atmosphere_of_Earth (N/A)
Time	Education (7)		Time	Biology (N/A)
Time	Television (8)		Time	Learning (N/A)
Tree	Oxygen (1)		Time	Leisure (N/A)
Tree	Forest (2)		Time	Music (N/A)
Tree	Water (3)		Travel	Water (N/A)
War	Hatred (1)		Tree	Forest (2)
War	Religion (2)		Tree	Plant (N/A)
War	Disease (3)		War	Peace (4)
War	Peace (4)		War	Human (N/A)
Water	Sea (1)		War	Death (N/A)
Water	Human (2)		War	Food (N/A)
Water	Rain (3)		Water	Sea (1)
Water	Oxygen (4)		Water	Rain (3)
Water	Organism (5)		Water	Oxygen (4)
Water	Sun (6)		Water	Plant (7)
Water	Plant (7)		Water	Food (N/A)
Water	Travel (8)		Water	Animal (N/A)
Water	Biology (9)		Water	Bread (N/A)
Water	Time (10)		Water	Money (N/A)
World	Human (1)		Water	Tree (N/A)
World	Experience (2)		Work	Leisure (N/A)

Appendix V

This listing shows the highest-ranking hyperlinked concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms (as explained in Subchapter 6.3).

Observed concept	Ranking based on repetition of hyperlink terms for observed concept		Observed concept	Ranking based on repetition of hyperlink terms for observed concept
Concept	End concepts for hyperlinks departing from observed concept (repetitions of hyperlink terms)		Concept	Start concepts for hyperlinks arriving to observed concept (repetitions of hyperlink terms)
Adolescence	Child (14)		Adolescence	Child (14)
Adolescence	Old_age (5)		Adolescence	Human (7)
Adolescence	Education (4)		Adolescence	Old_age (5)
Adolescence	Childhood (3)		Adolescence	Education (4)
Adolescence	Sport (1)		Adolescence	Childhood (3)
Adolescence	Television (1)		Adolescence	Dog (0)
Adolescence	Infant (0)		Adolescence	Friendship (0)
Animal	Plant (10)		Adolescence	Infant (0)
Animal	Evolution (8)		Animal	Plant (10)
Animal	Organism (8)		Animal	Biology (5)
Animal	Biology (5)		Animal	Food (2)
Animal	Water (3)		Animal	Human (2)
Animal	Human (2)		Animal	Atmosphere_of_Earth (0)
Animal	Time (2)		Animal	Birth (0)
Animal	Oxygen (1)		Animal	Eating (0)
Animal	Atmosphere_of_Earth (0)		Animal	Friendship (0)
Animal	Nature (0)		Animal	Nature (0)
Atmosphere_of_Earth	Oxygen (17)		Animal	Pet (0)
Atmosphere_of_Earth	Plant (4)		Atmosphere_of_Earth	Plant (4)
Atmosphere_of_Earth	Time (4)		Atmosphere_of_Earth	Animal (2)
Atmosphere_of_Earth	Evolution (3)		Atmosphere_of_Earth	Biology (0)
Atmosphere_of_Earth	Animal (2)		Atmosphere_of_Earth	Nature (0)
Atmosphere_of_Earth	Automobile (1)		Automobile	City (4)
Atmosphere_of_Earth	Organism (1)		Automobile	Oxygen (2)
Atmosphere_of_Earth	Biology (0)		Automobile	Atmosphere_of_Earth (0)
Atmosphere_of_Earth	Nature (0)		Bed	Dream (0)
Automobile	Oxygen (2)		Biology	Organism (57)
Bed	Hospital (4)		Biology	Evolution (24)
Bed	Infant (2)		Biology	Animal (14)
Bed	Dream (0)		Biology	Plant (9)
Biology	Organism (57)		Biology	Atmosphere_of_Earth (2)
Biology	Evolution (24)		Biology	Health (1)
Biology	Animal (14)		Biology	Nature (1)
Biology	Plant (9)		Biology	Education (0)
Biology	Human (8)		Biology	Love (0)
Biology	Time (3)		Biology	Old_age (0)
Biology	Atmosphere_of_Earth (2)		Biology	Water (0)
Biology	Health (1)		Birth	Parent (1)
Biology	Nature (1)		Book	Paper (31)
Birth	Mother (5)		Book	Hobby (0)
Birth	Death (2)		Bread	Food (17)
Birth	Animal (1)		Cat	Pet (22)
Birth	Sun (1)		Cat	Dog (20)
Book	Paper (31)		Child	Childhood (3)
Book	Music (0)		Child	Parent (2)
Bread	Water (20)		Child	Old_age (1)
Bread	Food (17)		Child	Adolescence (0)
Bread	Money (2)		Child	Education (0)
Bread	Paper (1)		Child	Family (0)
Cat	Human (62)		Child	Infant (0)
Cat	Pet (22)		Childhood	Child (26)
Cat	Dog (20)		Childhood	Human (1)
Child	Childhood (3)		Childhood	Adolescence (0)
Child	Parent (2)		Childhood	Education (0)
Child	Old_age (1)		Childhood	Infant (0)
Child	Adolescence (0)		Childhood	Old_age (0)
Child	Family (0)		City	Human (1)
Child	Infant (0)		Clock	Time (79)

Child	Leisure (0)		Clock	Future (0)
Child	Marriage (0)		Clothing	Human (10)
Child	Sibling (0)		Clothing	Paper (2)
Childhood	Child (26)		Clothing	Shoe (0)
Childhood	Adolescence (0)		Computer	Clock (0)
Childhood	Infant (0)		Computer	Food (0)
Childhood	Old_age (0)		Death	Disease (14)
City	Automobile (2)		Death	Future (5)
City	Religion (1)		Death	Diet_(nutrition) (2)
City	Rain (0)		Death	Food (2)
Clock	Time (79)		Death	Birth (0)
Clock	Computer (8)		Death	Marriage (0)
Clock	Future (0)		Death	Old_age (0)
Clothing	Paper (2)		Diet_(nutrition)	Food (17)
Clothing	Religion (2)		Diet_(nutrition)	Health (4)
Clothing	Television (1)		Diet_(nutrition)	Human (1)
Clothing	Marriage (0)		Diet_(nutrition)	Death (0)
Computer	Telephone (1)		Diet_(nutrition)	Physical_fitness (0)
Computer	Television (1)		Disease	Health (8)
Death	Disease (14)		Disease	Death (1)
Death	Human (13)		Disease	Hospital (1)
Death	Organism (13)		Disease	War (1)
Death	Evolution (7)		Disease	Oxygen (0)
Death	Oxygen (3)		Dog	Pet (19)
Death	Diet_(nutrition) (2)		Dog	Cat (9)
Death	Heart (2)		Dream	Bed (1)
Death	Physical_fitness (1)		Eating	Food (14)
Death	War (0)		Eating	Hobby (0)
Diet_(nutrition)	Health (4)		Eating	Leisure (0)
Diet_(nutrition)	Religion (2)		Education	Learning (48)
Diet_(nutrition)	Organism (1)		Education	School (34)
Diet_(nutrition)	Death (0)		Education	Teacher (8)
Disease	Death (1)		Education	Time (4)
Dog	Pet (19)		Education	Adolescence (2)
Dog	Cat (9)		Education	Leisure (1)
Dog	Adolescence (1)		Education	Test_(assessment) (1)
Dream	Bed (1)		Education	Hobby (0)
Dream	God (1)		Education	Peace (0)
Eating	Food (14)		Emotion	Human (15)
Eating	Animal (4)		Emotion	Sadness (9)
Eating	Human (2)		Emotion	Happiness (7)
Eating	Organism (1)		Emotion	Love (6)
Eating	Plant (1)		Emotion	Hatred (1)
Education	Learning (48)		Emotion	Marriage (1)
Education	School (34)		Emotion	Pleasure (1)
Education	Child (13)		Evolution	Organism (75)
Education	Philosophy (10)		Evolution	Human (28)
Education	Human (9)		Evolution	Biology (22)
Education	Teacher (8)		Evolution	Nature (20)
Education	Family (6)		Evolution	Animal (19)
Education	Adolescence (2)		Evolution	Flower (3)
Education	Childhood (2)		Evolution	Future (3)
Education	Biology (1)		Evolution	Religion (3)
Education	Leisure (1)		Evolution	Atmosphere_of_Earth (1)
Education	Marriage (1)		Evolution	Death (1)
Education	Sibling (0)		Evolution	Emotion (0)
Emotion	Experience (12)		Experience	Emotion (1)
Emotion	Sadness (9)		Experience	Learning (0)
Emotion	Happiness (7)		Experience	World (0)
Emotion	Love (6)		Family	Child (51)
Emotion	Hatred (1)		Family	Mother (13)
Emotion	Joy (1)		Family	Marriage (12)
Emotion	Pleasure (1)		Family	Father (8)
Emotion	Evolution (0)		Family	Human (5)
Evolution	Organism (75)		Family	Sibling (4)
Evolution	Plant (32)		Family	Education (3)
Evolution	Biology (22)		Family	Love (2)
Evolution	Philosophy (3)		Family	Home (1)
Evolution	Oxygen (1)		Family	Leisure (1)
Experience	Philosophy (2)		Family	House (0)
Experience	Time (1)		Family	Party (0)
Family	Child (51)		Father	Family (12)
Family	Mother (13)		Father	Mother (8)
Family	Marriage (12)		Father	Parent (4)
Family	Father (8)		Father	Sibling (1)

Family	Sibling (4)		Father	God (0)
Family	Leisure (1)		Flower	Plant (63)
Father	Family (12)		Flower	Forest (0)
Father	Mother (8)		Food	Health (19)
Father	Parent (4)		Food	Eating (3)
Father	Marriage (2)		Food	Bread (1)
Father	Sibling (1)		Food	Hobby (0)
Father	Love (0)		Food	Money (0)
Flower	Plant (63)		Forest	Tree (33)
Flower	Evolution (11)		Forest	Plant (6)
Food	Animal (30)		Friendship	Love (14)
Food	Health (19)		Future	Time (10)
Food	Diet_(nutrition) (16)		Future	Clock (0)
Food	Plant (14)		Goal	Purpose (1)
Food	Human (13)		Goal	Teacher (0)
Food	Water (5)		God	Religion (20)
Food	Eating (3)		God	Philosophy (9)
Food	War (2)		God	Time (4)
Food	Bread (1)		God	Human (2)
Food	Computer (1)		God	Dream (0)
Food	Death (1)		God	Marriage (0)
Food	School (1)		God	Purpose (0)
Forest	Tree (33)		Happiness	Emotion (8)
Forest	Plant (6)		Happiness	Human (5)
Forest	Rain (5)		Happiness	Pleasure (4)
Forest	Flower (0)		Happiness	Purpose (2)
Friendship	Love (14)		Happiness	Joy (1)
Friendship	Animal (7)		Happiness	Hatred (0)
Friendship	Philosophy (2)		Happiness	Love (0)
Friendship	Adolescence (0)		Happiness	Sadness (0)
Future	Time (10)		Hatred	Emotion (0)
Future	Human (4)		Hatred	Love (0)
Future	Evolution (2)		Hatred	Pleasure (0)
Future	Religion (2)		Hatred	Sadness (0)
Future	Death (1)		Hatred	War (0)
Future	Philosophy (1)		Health	Physical_fitness (10)
Future	Clock (0)		Health	Food (9)
Goal	Purpose (1)		Health	Human (8)
God	Religion (20)		Health	Diet_(nutrition) (6)
God	Nature (9)		Health	Biology (2)
God	Philosophy (9)		Health	Infant (1)
God	Father (1)		Health	Hospital (0)
Ground	Philosophy (1)		Heart	Oxygen (2)
Happiness	Emotion (8)		Heart	Death (1)
Happiness	Joy (1)		Heart	Organism (0)
Hatred	Emotion (0)		Home	House (1)
Hatred	Happiness (0)		Hospital	Bed (3)
Hatred	Love (0)		Hospital	Infant (0)
Hatred	Pleasure (0)		House	Home (12)
Hatred	Sadness (0)		House	Human (8)
Health	Disease (15)		House	Hobby (0)
Health	Physical_fitness (10)		Human	World (54)
Health	Food (9)		Human	Religion (46)
Health	Diet_(nutrition) (6)		Human	People (38)
Health	Biology (2)		Human	Nature (35)
Hobby	Sport (6)		Human	Food (30)
Hobby	Education (4)		Human	Animal (29)
Hobby	Food (3)		Human	Biology (20)
Hobby	Plant (3)		Human	Death (11)
Hobby	Book (1)		Human	Water (6)
Hobby	Eating (1)		Human	Eating (5)
Hobby	House (0)		Human	Future (4)
Hobby	Leisure (0)		Human	Parent (4)
Home	Family (1)		Human	Mother (3)
Home	House (1)		Human	Education (1)
Home	Love (1)		Human	Cat (0)
Hospital	Health (15)		Infant	Child (18)
Hospital	Disease (2)		Infant	Bed (1)
House	Home (12)		Infant	Childhood (1)
House	Family (7)		Infant	Old_age (1)
House	Pet (1)		Infant	Adolescence (0)
House	Television (1)		Joy	Emotion (1)
Human	Evolution (72)		Joy	Happiness (1)
Human	Religion (46)		Learning	Education (5)
Human	Emotion (35)		Learning	Teacher (1)

Human	War (35)		Leisure	Education (3)
Human	Animal (29)		Leisure	Family (2)
Human	Diet_(nutrition) (29)		Leisure	Hobby (2)
Human	Philosophy (28)		Leisure	Child (1)
Human	Music (22)		Leisure	Marriage (1)
Human	Health (15)		Leisure	Mother (1)
Human	Family (12)		Light	Time (11)
Human	Old_age (11)		Light	Plant (0)
Human	Love (10)		Love	Human (13)
Human	House (9)		Love	Friendship (8)
Human	City (8)		Love	Emotion (4)
Human	Childhood (5)		Love	Mother (4)
Human	God (5)		Love	Pleasure (3)
Human	Adolescence (4)		Love	Hatred (1)
Human	Clothing (4)		Love	Marriage (1)
Human	Happiness (4)		Love	Sadness (1)
Human	Oxygen (1)		Love	Father (0)
Infant	Child (18)		Love	Home (0)
Infant	Health (8)		Love	Sibling (0)
Infant	Childhood (1)		Marriage	Family (38)
Infant	Hospital (1)		Marriage	Child (23)
Infant	Old_age (1)		Marriage	Education (4)
Infant	Adolescence (0)		Marriage	Love (4)
Joy	Happiness (1)		Marriage	Mother (4)
Learning	Time (6)		Marriage	Father (2)
Learning	Education (5)		Marriage	Leisure (1)
Learning	Experience (5)		Marriage	Sibling (1)
Learning	Physical_fitness (1)		Marriage	Clothing (0)
Leisure	Time (22)		Money	Bread (0)
Leisure	Work (13)		Mother	Father (3)
Leisure	Education (3)		Mother	Family (2)
Leisure	Family (2)		Mother	Parent (2)
Leisure	Eating (1)		Mother	Birth (1)
Leisure	Marriage (1)		Mother	Sibling (0)
Leisure	Television (1)		Music	Human (7)
Leisure	Sibling (0)		Music	Book (5)
Light	Time (11)		Music	Pleasure (2)
Light	Sun (7)		Music	Party (0)
Light	Television (2)		Music	Philosophy (0)
Love	Friendship (8)		Music	Test_(assessment) (0)
Love	Family (6)		Nature	Plant (31)
Love	Emotion (4)		Nature	Animal (25)
Love	Biology (3)		Nature	Atmosphere_of_Earth (17)
Love	Pleasure (3)		Nature	Biology (2)
Love	Religion (3)		Nature	God (0)
Love	Happiness (2)		Old_age	Human (2)
Love	Hatred (1)		Old_age	Child (1)
Love	Marriage (1)		Old_age	Adolescence (0)
Love	Philosophy (1)		Old_age	Childhood (0)
Love	Sadness (1)		Old_age	Infant (0)
Marriage	Family (38)		Organism	Animal (15)
Marriage	Religion (14)		Organism	Plant (12)
Marriage	Death (5)		Organism	Evolution (10)
Marriage	God (5)		Organism	Biology (6)
Marriage	Love (4)		Organism	Atmosphere_of_Earth (1)
Marriage	Leisure (1)		Organism	Nature (1)
Marriage	Sibling (1)		Organism	Death (0)
Marriage	Emotion (0)		Organism	Diet_(nutrition) (0)
Money	Water (2)		Organism	Eating (0)
Money	Food (1)		Organism	Water (0)
Mother	Father (3)		Oxygen	Water (41)
Mother	Family (2)		Oxygen	Atmosphere_of_Earth (19)
Mother	Parent (2)		Oxygen	Plant (11)
Mother	Human (1)		Oxygen	Nature (8)
Mother	Leisure (0)		Oxygen	Animal (6)
Mother	Love (0)		Oxygen	Evolution (6)
Mother	Marriage (0)		Oxygen	Human (3)
Mother	Sibling (0)		Oxygen	Automobile (1)
Music	Time (10)		Oxygen	Death (1)
Music	Television (1)		Oxygen	Sun (0)
Music	Religion (0)		Oxygen	Tree (0)
Nature	Human (39)		Paper	Book (9)
Nature	Plant (31)		Paper	Clothing (1)
Nature	Animal (25)		Paper	Pen (1)
Nature	Atmosphere_of_Earth (17)		Paper	Bread (0)

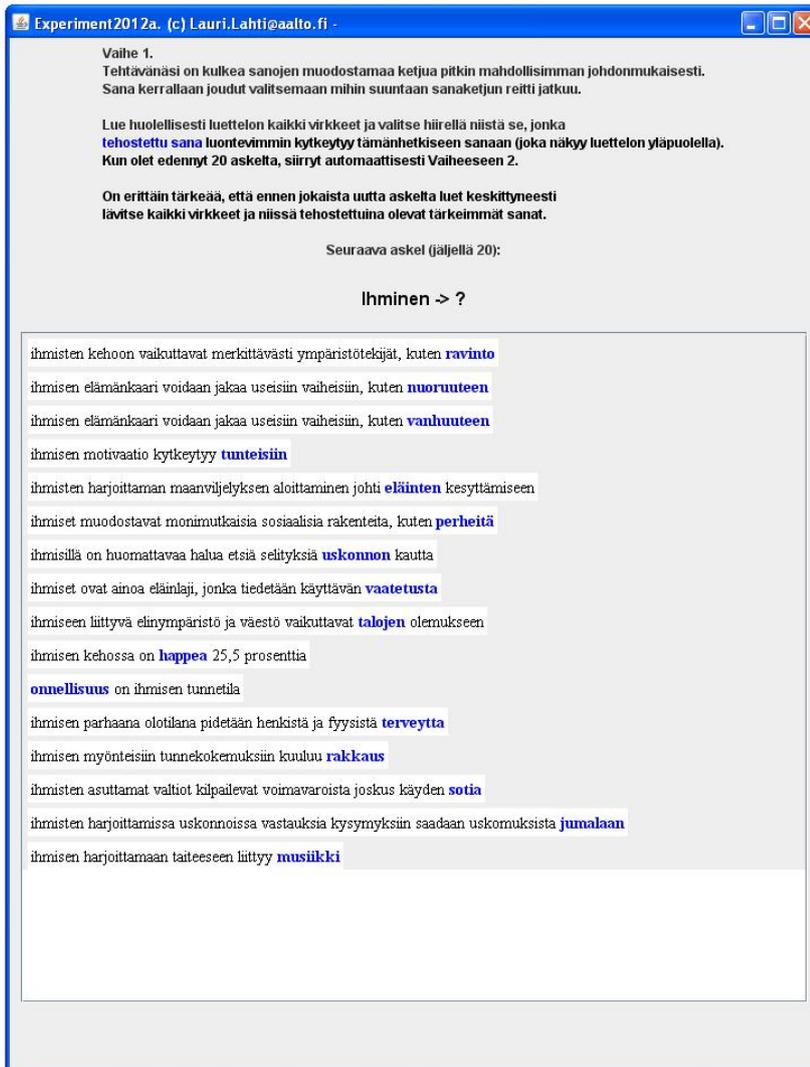
Nature	Organism (11)		Parent	Mother (24)
Nature	Time (7)		Parent	Father (11)
Nature	Evolution (5)		Parent	Child (10)
Nature	Oxygen (4)		Parent	Sibling (2)
Nature	Sun (4)		Peace	War (8)
Nature	Biology (2)		People	Pet (0)
Old_age	Biology (1)		Pet	Cat (20)
Old_age	Child (1)		Pet	Dog (18)
Old_age	Adolescence (0)		Pet	House (0)
Old_age	Childhood (0)		Philosophy	Human (23)
Old_age	Death (0)		Philosophy	Experience (10)
Old_age	Infant (0)		Philosophy	Time (10)
Organism	Plant (12)		Philosophy	People (9)
Organism	Evolution (10)		Philosophy	Religion (7)
Organism	Biology (6)		Philosophy	Education (3)
Organism	Heart (1)		Philosophy	Future (3)
Oxygen	Water (41)		Philosophy	God (3)
Oxygen	Plant (11)		Philosophy	Love (2)
Oxygen	Heart (2)		Philosophy	Friendship (1)
Oxygen	Automobile (1)		Philosophy	Ground (1)
Oxygen	Disease (1)		Philosophy	Pleasure (1)
Oxygen	Philosophy (1)		Philosophy	Purpose (1)
Oxygen	Rain (1)		Philosophy	Evolution (0)
Oxygen	Sport (1)		Philosophy	Oxygen (0)
Oxygen	Sun (0)		Philosophy	Test_(assessment) (0)
Paper	Book (9)		Physical_fitness	Health (3)
Paper	Clothing (1)		Physical_fitness	Death (0)
Parent	Mother (24)		Physical_fitness	Learning (0)
Parent	Father (11)		Plant	Food (13)
Parent	Child (10)		Plant	Animal (12)
Parent	Human (4)		Plant	Water (10)
Parent	Birth (2)		Plant	Biology (8)
Parent	Sibling (2)		Plant	Evolution (7)
Party	Music (7)		Plant	Organism (7)
Party	Family (3)		Plant	Flower (6)
Party	Television (2)		Plant	Forest (6)
Peace	War (8)		Plant	Atmosphere_of_Earth (4)
Peace	Education (1)		Plant	Oxygen (4)
Pen	Paper (3)		Plant	Nature (2)
People	Human (5)		Plant	Eating (1)
People	Philosophy (4)		Plant	Hobby (0)
People	Religion (3)		Plant	Rain (0)
People	Purpose (2)		Plant	Summer (0)
Pet	Animal (40)		Plant	Sun (0)
Pet	Cat (20)		Pleasure	Love (2)
Pet	Dog (18)		Pleasure	Emotion (0)
Pet	People (11)		Pleasure	Hatred (0)
Philosophy	Religion (7)		Pleasure	Sadness (0)
Philosophy	God (3)		Purpose	Goal (5)
Philosophy	Music (2)		Purpose	People (5)
Physical_fitness	Health (3)		Rain	Water (14)
Physical_fitness	Diet_(nutrition) (1)		Rain	City (2)
Plant	Tree (16)		Rain	Forest (0)
Plant	Animal (12)		Rain	Oxygen (0)
Plant	Water (10)		Religion	God (18)
Plant	Biology (8)		Religion	Philosophy (16)
Plant	Organism (7)		Religion	Human (12)
Plant	Flower (6)		Religion	People (12)
Plant	Forest (6)		Religion	War (2)
Plant	Atmosphere_of_Earth (4)		Religion	Future (1)
Plant	Light (4)		Religion	Time (1)
Plant	Oxygen (4)		Religion	City (0)
Plant	Nature (2)		Religion	Clothing (0)
Plant	Time (1)		Religion	Diet_(nutrition) (0)
Pleasure	Philosophy (3)		Religion	Love (0)
Pleasure	Love (2)		Religion	Marriage (0)
Pleasure	Happiness (1)		Religion	Music (0)
Pleasure	Music (1)		Sadness	Emotion (3)
Pleasure	Emotion (0)		Sadness	Sorrow (1)
Pleasure	Hatred (0)		Sadness	Hatred (0)
Pleasure	Sadness (0)		Sadness	Love (0)
Purpose	Happiness (8)		Sadness	Pleasure (0)
Purpose	Philosophy (8)		School	Education (23)
Purpose	Goal (5)		School	Teacher (7)
Purpose	God (1)		School	Food (0)

Rain	Water (14)		Sea	Water (9)
Rain	Plant (6)		Sibling	Child (32)
Rain	Sun (1)		Sibling	Parent (16)
Religion	God (18)		Sibling	Family (14)
Religion	Philosophy (16)		Sibling	Father (3)
Religion	Human (12)		Sibling	Marriage (3)
Religion	Evolution (3)		Sibling	Mother (2)
Religion	Sun (2)		Sibling	Education (0)
Sadness	Emotion (3)		Sibling	Leisure (0)
Sadness	Happiness (2)		Sorrow	Sadness (1)
Sadness	Sorrow (1)		Sport	Adolescence (0)
Sadness	Hatred (0)		Sport	Hobby (0)
Sadness	Love (0)		Sport	Oxygen (0)
Sadness	Pleasure (0)		Sun	Light (24)
School	Education (23)		Sun	Water (6)
School	Teacher (7)		Sun	Nature (4)
Sea	Water (9)		Sun	Oxygen (3)
Shoe	Clothing (1)		Sun	Birth (0)
Sibling	Parent (16)		Sun	Rain (0)
Sibling	Family (14)		Sun	Religion (0)
Sibling	Love (4)		Teacher	School (22)
Sibling	Father (3)		Teacher	Education (20)
Sibling	Marriage (3)		Teacher	Test_(assessment) (0)
Sibling	Mother (2)		Telephone	Computer (2)
Sorrow	Sadness (1)		Television	Time (6)
Sport	Television (4)		Television	Music (3)
Summer	Plant (1)		Television	Adolescence (0)
Sun	Oxygen (3)		Television	Clothing (0)
Sun	Plant (2)		Television	Computer (0)
Teacher	School (22)		Television	House (0)
Teacher	Education (20)		Television	Leisure (0)
Teacher	Learning (5)		Television	Light (0)
Teacher	Goal (0)		Television	Party (0)
Test_(assessment)	Education (5)		Television	Sport (0)
Test_(assessment)	Teacher (3)		Time	Clock (24)
Test_(assessment)	Music (1)		Time	Light (14)
Test_(assessment)	Philosophy (1)		Time	Future (12)
Time	Philosophy (26)		Time	Experience (10)
Time	Clock (24)		Time	Nature (10)
Time	Light (14)		Time	Plant (1)
Time	Future (12)		Time	Water (1)
Time	God (6)		Time	Animal (0)
Time	Religion (3)		Time	Atmosphere_of_Earth (0)
Time	Education (1)		Time	Biology (0)
Time	Television (1)		Time	Learning (0)
Tree	Forest (5)		Time	Leisure (0)
Tree	Water (3)		Time	Music (0)
Tree	Oxygen (1)		Travel	Water (0)
War	Peace (21)		Tree	Plant (14)
War	Religion (4)		Tree	Forest (5)
War	Disease (3)		War	Human (23)
War	Hatred (2)		War	Peace (21)
Water	Human (27)		War	Death (15)
Water	Sea (14)		War	Food (2)
Water	Oxygen (11)		Water	Food (26)
Water	Time (9)		Water	Sea (14)
Water	Plant (8)		Water	Oxygen (11)
Water	Rain (8)		Water	Plant (8)
Water	Sun (5)		Water	Rain (8)
Water	Organism (2)		Water	Animal (5)
Water	Travel (1)		Water	Bread (0)
Water	Biology (0)		Water	Money (0)
World	Human (5)		Water	Tree (0)
World	Experience (2)		Work	Leisure (0)

Appendix W

User interfaces of a prototype tools used by experiment group (n=49) and control group (n=24) to perform an exploration task (texts provided only in Finnish), as discussed in Subchapter 10.1.

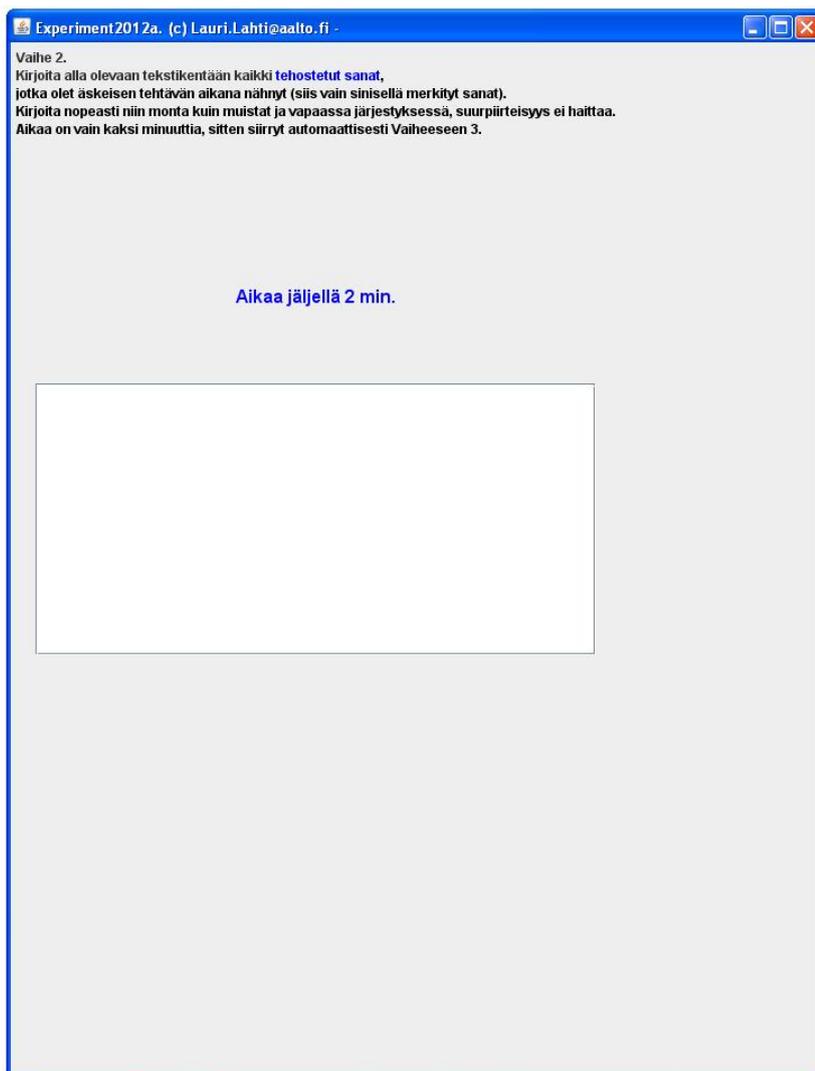
User interface of a prototype tool used by experiment group (n=49) for exploration phase:



User interface of a prototype tool used by control group (n=24) for exploration phase:



User interface of a prototype tool used by both experiment group (n=49) and control group (n=24) for recalling phase:



User interface of a prototype tool used by both experiment group (n=49) and control group (n=24) for phase of giving background information:

Experiment2012a. (c) Lauri.Lahti@aalto.fi

Vaihe 3.
Anna itsestäsi seuraavat taustatiedot
ja paina sitten lopuksi painiketta Tallentaminen.

Nimesi/
nimimerkki: Ikäsi: Valitse: Sukupuolesi: Valitse: Kuinka hyvin
mielestäsi menestyt
koulussa? Valitse:

Jos vertaat perinteiseen kirjasta opiskeluun,
niin äsken kokeilemasi menetelmä luetun
omaksumiseen vaikuttaa... Valitse:

Opiskelijana oletko kiinnostunut
käyttämään äsken kokeilemaasi
menetelmää luetun omaksumiseen? Valitse:

Kuinka helppoa sinulle itsellesi on omaksua
uutta asiaa lukemalla? Valitse:

Kirjoita tähän kehitysehdotuksia
ja muuta palautetta, jos haluat.
Mielellään myös sähköpostiosoitteesi,
jotta voimme jatkossakin pyytää sinua
auttamaan opetusmenetelmien tutkimuksessa.

Tallentaminen
(paina kun saat työsi valmiiksi)

In Subchapter 10.1 two learning cases are compared by asking an experiment group and a control group to perform an exploration task. Each member of the control group (n=24) had to proceed a predefined fixed series of twenty text pages, each one of them providing same kind of sentences with highlighted hyperlinked concepts as for the experiment group but without continuity between these pages and without possibility to select a hyperlink to proceed next while keeping continuity between pieces of knowledge. The predefined fixed series of twenty text pages the students had to proceed is listed here in this Appendix W.. Each of twenty pages represented a concept so that all hyperlinked concepts on this page corresponded to hyperlinks going from concept represented by this page to all those hyperlinked concepts and thus all hyperlinked concepts on same page had a shared start concept. However when proceeding to next page the concept represented by the next page was not any of those hyperlinked concepts of previous page and thus continuity between consecutive pages was minimized on purpose.

Sentences of twenty pages are based on relation statements of 212 hyperlinks belonging to “hyperlink network of 55 concepts” (shown in Appendix J) that was used in exploration task of experiment group (as explained in Subchapter 10.1). In relation statement the start concept has been indicated with a notation starting with character string “A1” and ending with character string “A2” and the end concept has been indicated with a notation starting with character string “B1” and ending with character string “B2”. These notations helped to automatically highlight with different colors both start concept and end concept in relation statement when it was shown to the student during exploration experiment.

English version:

<p>Page 1: concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2; A1humanA2 life span can be split into a number of stages like B1adolescenceB2; A1humanA2 life span can be split into a number of stages like B1old ageB2; concerning A1humansA2 motivation is connected to B1emotionsB2; advent of agriculture by A1humansA2 led to domestication of B1animalsB2; A1humansA2 create complex social structures such as B1familiesB2; A1humansA2 are noted for their desire seeking explanations through B1religionB2; A1humansA2 are the only species known to B1clotheB2 themselves; concerning A1humansA2 habitat and population influence characteristics of B1housesB2; A1humanA2 body contains 25.5 percent B1oxygenB2; B1happinessB2 is a A1humanA2 emotional condition; the best condition for A1humanA2 can be considered mental and physical B1healthB2; concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2; B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources; concerning A1humanA2 religions a common source for answers to questions are beliefs in B1godB2; concerning A1humansA2 art is connected to B1musicB2;</p>
<p>Page 2: A1educationA2 encompasses teaching and B1learningB2 specific skills; A1educationA2 in secondary school occurs during B1adolescenceB2; A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are; progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate; A1educationA2 is a means to foster future development of B1humansB2; educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2; in A1educationA2 informal relationships can be established between B1teachersB2 and students; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2;</p>
<p>Page 3: concerning A1familyA2 a B1motherB2 is a female parent; concerning A1familyA2 a B1fatherB2 is a male parent; in A1familyA2 a B1siblingB2 is a child of the same parents; A1familyA2 serves to give social orientation for B1childrenB2; according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2;</p>
<p>Page 4: A1deathA2 is the end of the life of a biological B1organismB2; many factors can contribute to an organism's A1deathA2, including B1diseaseB2; A1deathA2 was once defined as the cessation of beating of B1heartB2; a loss of homeostasis of body related to A1deathA2 causes loss of B1oxygenB2; causes of A1deathA2 can be postponed by B1dietB2; an autopsy is examination of a B1humanB2 corpse to determine the cause of a person's A1deathA2; B1warB2 can be considered as a situation whereby A1deathA2 assumes absolute value (taken from article War);</p>

<p>Page 5: A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees; fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2; most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide; among A1plantsA2 conifers are dominant B1treesB2; growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2; concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2; in B1natureB2 human has contributed to the extinction of many A1plantsA2; concerning A1plantsA2 in nature B1biologyB2 has a central role for life;</p>
<p>Page 6: A1childA2 as a term may define a relationship with a B1parentB2 or authority; B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2; B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2;</p>
<p>Page 7: A1animalsA2 are multicellular B1organismsB2; when talking about A1animalsA2 it is often referred to other animals than B1humansB2; A1animalsA2 generally digest food internally which separates them from B1plantsB2; A1animalsA2 benefit from plants which with carbon dioxide and B1waterB2 store the energy of sunlight; A1animalsA2 benefit from process in which the energy of sunlight helps to release B1oxygenB2; in nature B1biologyB2 has a central role for life such as A1animalsA2;</p>
<p>Page 8: A1loveA2 has many different meanings ranging to something one would die for, like B1familyB2; A1loveA2 can describe an intense feeling of affection, an B1emotionB2 or an emotional state; A1loveA2 is connected to emotions about B1happinessB2; concerning A1loveA2 B1friendshipB2 means the spirit between friends; throughout history, philosophy and B1religionB2 have done the most speculation on the phenomenon of A1loveA2; according to B1biologyB2 there are two major drives in A1loveA2: sexual attraction and attachment;</p>
<p>Page 9: components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe; existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2; the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2; liquid A1waterA2 is found in bodies of water such as B1seaB2; there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2; concerning A1waterA2 rivers and seas offer opportunity for B1travelB2; storage of A1waterA2 is important, since it is essential to B1humanB2 life; from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life;</p>
<p>Page 10: concerning A1religionA2 Isaac Newton believed that the planets revolve about the B1SunB2 and credited God with the design; A1religionA2 is related to awareness of B1GodB2 through direct personal experience; concerning A1religionA2 B1humansB2 have methods which attempt to answer fundamental questions;</p>
<p>Page 11: A1oxygenA2 in the form of O2 is produced from water e.g. by B1plantsB2 during photosynthesis; near the earth's surface ozone consisting of A1oxygenA2 is a pollutant formed from B1automobileB2 exhaust; A1oxygen therapy is used to treat B1heartB2 disorders; A1oxygen therapy is used to treat B1diseasesB2 that impair the ability to use gaseous oxygen; B1waterB2 (H2O) is the oxide of hydrogen and the most familiar A1oxygenA2 compound;</p>
<p>Page 12: part of B1biologyB2 related to A1ageingA2 is called senescence; A1old ageA2 is a stage of life preceding B1deathB2; B1childB2 is a legally important stage in personal development like also A1old ageA2; B1adolescenceB2 is a legally important stage in personal development like A1old ageA2;</p>
<p>Page 13: A1educationA2 encompasses teaching and B1learningB2 specific skills; A1educationA2 in secondary school occurs during B1adolescenceB2; A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are; progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate; A1educationA2 is a means to foster future development of B1humansB2; educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2; in A1educationA2 informal relationships can be established between B1teachersB2 and students; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2;</p>
<p>Page 14: A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees; fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2; most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide; among A1plantsA2 conifers are dominant B1treesB2; growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2; concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2; concerning A1plantsA2 in nature B1biologyB2 has a central role for life;</p>
<p>Page 15: A1childA2 as a term may define a relationship with a B1parentB2 or authority; B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2; B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1brotherhoodB2;</p>

<p>according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2;</p>
<p>Page 16: concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2; A1humanA2 life span can be split into a number of stages like B1adolescenceB2; A1humanA2 life span can be split into a number of stages like B1old ageB2; concerning A1humansA2 motivation is connected to B1emotionsB2; advent of agriculture by A1humansA2 led to domestication of B1animalsB2; A1humansA2 create complex social structures such as B1familiesB2; A1humansA2 are noted for their desire seeking explanations through B1religionB2; A1humansA2 are the only species known to B1clotheB2 themselves; concerning A1humansA2 habitat and population influence characteristics of B1housesB2 ; A1humanA2 body contains 25.5 percent B1oxygenB2; B1happinessB2 is a A1humanA2 emotional condition; the best condition for A1humanA2 can be considered mental and physical B1healthB2; concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2; B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources; concerning A1humansA2 art is connected to B1musicB2;</p>
<p>Page 17: A1deathA2 is the end of the life of a biological B1organismB2; many factors can contribute to an organism's A1deathA2, including B1diseaseB2; A1deathA2 was once defined as the cessation of beating of B1heartB2; a loss of homeostasis of body related to A1deathA2 causes loss of B1oxygenB2; causes of A1deathA2 can be postponed by B1dietB2; B1warB2 can be considered as a situation whereby A1deathA2 assumes absolute value (taken from article War);</p>
<p>Page 18: components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe; existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2; the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2; liquid A1waterA2 is found in bodies of water such as B1seaB2; there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2; storage of A1waterA2 is important, since it is essential to B1humanB2 life; from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life;</p>
<p>Page 19: concerning A1familyA2 a B1motherB2 is a female parent; concerning A1familyA2 a B1fatherB2 is a male parent; in A1familyA2 a B1siblingB2 is a child of the same parents; A1familyA2 serves to give social orientation for B1childrenB2; according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2;</p>
<p>Page 20: concerning A1natureA2 one part of the Earth is more exposed to the rays of the B1SunB2; in A1natureA2 biological manifestation of life concerning B1organismsB2 is characterized by organization; in A1natureA2 properties common to organisms, such as B1plantsB2, are that they are cellular; in A1natureA2 properties common to organisms, such as B1animalsB2, are that they are cellular; in A1natureA2 B1biologyB2 has a central role for life; in A1natureA2 wilderness is generally defined as an environment that has not been directly modified by B1humanB2;</p>

Finnish version:

<p>Page 1: A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristötekijät, kuten B1ravintoB2; A1ihmisenA2 elämänskaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2; A1ihmisenA2 elämänskaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2; A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2; A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesyttämiseen; A1ihmisetA2 muodostavat monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2; A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta; A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2; A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen; A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia; B1onnellisuusB2 on A1ihmisenA2 tunnetila; A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2; A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2; A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2; A1ihmistenA2 harjoittamissa uskonnoissa vastauksia kysymyksiin saadaan uskomuksista B1jumalaanB2; A1ihmisenA2 harjoittamaan taiteeseen liittyy B1musiikkiB2;</p>
<p>Page 2: A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2; yläluokilla tarjottava A1koulutusA2 tapahtuu B1nuoruudenB2 aikana; A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat; A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa; A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittymistä; A1koulutustaA2 koskeva kasvatustieteologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2; A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin;</p>

<p>myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 3: A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi; A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi; A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat; A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti; myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2;</p>
<p>Page 4: A1kuolemaA2 on biologisen B1eliönB2 elämän päätyminen; eliön A1kuolemaanA2 voivat vaikuttaa useat tekijät mukaan lukien B1sairaudetB2; aikoinaan A1kuolemaA2 määriteltiin B1sydämenB2 lyönnin pysähtymisenä; A1kuolemaanA2 liittyvä elimistön tasapainon menetys aiheuttaa B1hapenB2 puutetta; syitä A1kuolemaanA2 voidaan lykätä B1ravinnollaB2; ruumiinavaus on B1ihmisenB2 ruumiin tutkiminen A1kuolemanA2 syyn selvittämiseksi; B1sotaaB2 voidaan pitää tilanteena, jossa A1kuolemaA2 saa ehdottoman aseman;</p>
<p>Page 5: A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita; sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2; useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoaB2 ja hiilidioksisia; A1kasvienA2 joukossa paljassiemeniset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä; A1kasvienA2 kasvu määräytyy myös ympäristötekijöistä, kuten saatavilla olevasta B1vedestäB2; A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakehää, jossa on nykyisin 21 prosenttia B1happeaB2; B1luonnossaB2 ihminen on vaikuttanut useiden A1kasvienA2 sukupuuttoon; A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle;</p>
<p>Page 6: A1lapsiA2 käsitteenä voi määrittellä suhteen B1vanhempaanB2 tai auktoriteettiin; B1vanhuusB2 on kypsynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 7: A1eläimetA2 ovat monisoluisia B1eliöitäB2; A1eläimistäA2 puhuttaessa usein viitataan muihin eläimiin kuin B1ihmisiinB2; A1eläimetA2 yleensä sulattavat ravinnon sisäisesti mikä erottaa ne B1kasveistaB2; A1eläimetA2 hyötyvät kasveista jotka hiilidioksidin ja B1vedenB2 avulla varastoivat auringonvalon energiaa ; A1eläimetA2 hyötyvät siitä että auringonvalon energian avulla vapautuu B1happeaB2; luonnossa B1biologiallaB2 on keskeinen merkitys elämälle, kuten A1eläimilleA2;</p>
<p>Page 8: A1rakkaudellaA2 on eri merkityksiä ulottuen johonkin, jonka puolesta kuolla, kuten B1perheB2; A1rakkausA2 voi tarkoittaa kiihkeää kiintymystä, B1tunnettaB2 tai tunnetilaa; A1rakkauteenA2 liittyy tunteita B1onnellisuudestaB2; A1rakkauteenA2 liittyen B1ystävyyttäB2 merkitsee ystävien välillä vallitsevaa yhteishenkeä; läpi historian filosofia ja B1uskontoB2 ovat eniten spekuloineet A1rakkaudenA2 ilmiöllä; B1biologianB2 perusteella A1rakkaudelleA2 on kaksi vaikutinta: seksuaalinen vetovoima ja kiintymys;</p>
<p>Page 9: A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa; A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2; maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa; nestemäistä A1vettäA2 esiintyy vesistöissä, kuten B1meressäB2; A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta; A1veteenA2 liittyen joet ja meret tarjoavat tilaisuuden B1matkustamiselleB2; A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle; B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiseksi;</p>
<p>Page 10: A1uskontoonA2 liittyen Isaac Newton uskoi, että planeetat pyörivät B1auringonB2 ympäri jumalan suunnittelutyön seurauksena; A1uskontoonA2 liittyy tietoisuus B1jumalastaB2 suoran henkilökohtaisen kokemuksen kautta; A1uskontoaA2 koskien B1ihmisilläB2 on menetelmiä vastauksen saamiseksi perimmäisiin kysymyksiin;</p>
<p>Page 11: A1happiA2 muodossa O2 syntyy vedestä mm. B1kasvienB2 yhteyttämisen kautta; A1hapestaaA2 koostuva otsoni on maan pinnalla saaste, joka syntyy B1autojenB2 pakokaasuista; A1happiA2terapiaa käytetään B1sydämenB2 häiriöiden hoitoon; A1happiA2terapiaa käytetään B1sairauksienB2 hoitoon, jotka vaikeuttavat hapen käyttöä; B1vesiB2 (H2O) on vedyn oksidi ja yleisin A1happiA2yhdiste;</p>
<p>Page 12: A1vanhuuteenA2 liittyvää B1biologianB2 osa-aluetta kutsutaan seneskenssiksi; A1vanhuusA2 on B1kuolemaaB2 edeltävä elämänvaihe; B1lapsiB2 on oikeudellisesti tärkeässä yksilönkehityksen vaiheessa, jollainen on myös A1vanhuusA2; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, kuten A1vanhuusA2;</p>
<p>Page 13: A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2; yläluokilla tarjottava A1koulutusA2 tapahtuu B1nuoruudenB2 aikana; A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat; A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa; A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittymistä; A1koulutustaA2 koskeva kasvatustieteellinen psykologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2; A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä;</p>

<p>myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 14: A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita; sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2; useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoaB2 ja hiilidioksisia; A1kasvienA2 joukossa paljassiemieniset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä; A1kasvienA2 kasvu määräytyy myös ympäristökiteijöistä, kuten saatavilla olevasta B1vedestäB2; A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakehää, jossa on nykyisin 21 prosenttia B1happeaB2; A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle;</p>
<p>Page 15: A1lapsiA2 käsitteenä voi määritellä suhteen B1vanhempaanB2 tai auktoriteettiin; B1vanhuusB2 on kypsytynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 16: A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristökiteijat, kuten B1ravintoB2; A1ihmisenA2 elämäankaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2; A1ihmisenA2 elämäankaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2; A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2; A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesyttämiseen; A1ihmisetA2 muodostavat monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2; A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta; A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2; A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen; A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia; B1onnellisuusB2 on A1ihmisenA2 tunnetila; A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2; A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2; A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2; A1ihmisenA2 harjoittamaan taiteeseen liittyy B1musiikkiB2;</p>
<p>Page 17: A1kuolemaA2 on biologisen B1eliönB2 elämän päättymisen; eliön A1kuolemaanA2 voivat vaikuttaa useat tekijät mukaan lukien B1sairaudetB2; aikoinaan A1kuolemaA2 määriteltiin B1sydämenB2 lyönnin pysähtymisenä; A1kuolemaanA2 liittyvä elimistön tasapainon menetys aiheuttaa B1hapenB2 puutetta; syitä A1kuolemaanA2 voidaan lykätä B1ravinnollaB2; B1sotaaB2 voidaan pitää tilanteena, jossa A1kuolemaA2 saa ehdottoman aseman;</p>
<p>Page 18: A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa; A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2; maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa; nestemäistä A1vettäA2 esiintyy vesistöissä, kuten B1meressäB2; A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta; A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle; B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiseksi;</p>
<p>Page 19: A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi; A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi; A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat; A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti; myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2;</p>
<p>Page 20: A1luontoonA2 liittyen osa maapallosta on enemmän altistettuna B1auringonB2 säteille; A1luonnossaA2 B1eliöitäB2 koskeva elämä ilmenee biologisesti mm. järjestäytymisenä; A1luonnossaA2 eliöille, kuten B1kasveilleB2, yleisiä ominaisuuksia on koostuminen soluista; A1luontoonA2 liittyen eliöille, kuten B1eläimilleB2, yleisiä ominaisuuksia on koostuminen soluista; A1luonnossaA2 B1biologiallaB2 on keskeinen merkitys elämälle; A1luonnossaA2 erämaana pidetään ympäristöä, jota B1ihminenB2 ei ole suoraan muokannut;</p>

Appendix X

This is a listing of background characteristics of members of experiment group (n=49) and control group (n=24) as discussed in Subchapter 10.1. For four questions the student replied by selecting a most suitable answer from a scale of five given alternatives that are listed here next.

Response alternatives for question “If you compare to traditional learning from a book, then the method you have tried for adopting knowledge through reading appears to be...”:

Much more useful; Somewhat more useful; Equally useful; Somewhat less useful; or Much less useful.

(In Finnish: Jos vertaat perinteiseen kirjasta opiskeluun, niin äsken kokeilemasi menetelmä luetun omaksumiseen vaikuttaa... Paljon hyödyllisemmältä; Jonkin verran hyödyllisemmältä; Yhtä hyödylliseltä; Jonkin verran hyödyttömämmältä; tai Paljon hyödyttömämmältä.)

Response alternatives for question “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”:

It is very probable; It is probable; Perhaps; It is improbable; or It is very improbable.

(In Finnish: Opiskelijana oletko kiinnostunut käyttämään äsken kokeilemaasi menetelmää luetun omaksumiseen? Erittäin todennäköisesti; Todennäköisesti; Ehkä; Epätodennäköisesti; tai Erittäin epätodennäköisesti.)

Response alternatives for question “How easy it is for you to adopt new knowledge through reading?”:

Very easy; Easy; Moderate; Difficult; or Very difficult.

(In Finnish: Kuinka helppoa sinulle itsellesi on omaksua uutta asiaa lukemalla? Erittäin helppoa; Helppoa; Kohtalaista; Vaikeaa; tai Erittäin vaikeaa.)

Response alternatives for question “In your opinion, how successfully do you perform at school?”:

Excellently; Well; Satisfactorily; Fairly; or Faintly.

(In Finnish: Kuinka hyvin mielestäsi menestyt koulussa? Erinomaisesti; Hyvin; Tyydyttävästi; Välttävästi; tai Heikosti.)

Background characteristics of members of experiment group (n=49), see Subchapter 10.1 for details:

Unique identifier for each member of experiment group	Age	Gender	Response to question: “If you compare to traditional learning from a book, then the method you have tried for adopting knowledge through reading appears to be...”	Response to question: “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”	Response to question “How easy it is for you to adopt new knowledge through reading?”	Response to question “In your opinion, how successfully do you perform at school?”
E1	17	Female	Equally useful	Perhaps	Very easy	Well
E2	18	Female	Somewhat less useful	Perhaps	Moderate	Satisfactorily
E3	18	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E4	18	Female	Somewhat more useful	It is probable	Moderate	Satisfactorily
E5	17	Male	Somewhat less	It is probable	Moderate	Well

			useful			
E6	17	Male	Somewhat more useful	It is probable	Difficult	Satisfactorily
E7	18	Female	Somewhat more useful	It is probable	Very easy	Excellently
E8	18	Female	Somewhat more useful	Perhaps	Moderate	Well
E9	18	Female	Somewhat more useful	Perhaps	Easy	Well
E10	17	Female	Somewhat more useful	It is probable	Easy	Well
E11	17	Male	Much more useful	Perhaps	Difficult	Satisfactorily
E12	19	Male	Somewhat more useful	Perhaps	Easy	Satisfactorily
E13	17	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E14	17	Male	Somewhat more useful	It is probable	Moderate	Excellently
E15	18	Female	Somewhat more useful	It is very probable	Moderate	Satisfactorily
E16	17	Male	Somewhat less useful	It is probable	Moderate	Satisfactorily
E17	16	Male	Much more useful	It is very improbable	Very easy	Excellently
E18	17	Male	Much more useful	It is very probable	Moderate	Fairly
E19	16	Female	Equally useful	Perhaps	Moderate	Well
E20	17	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily
E21	18	Male	Somewhat more useful	Perhaps	Difficult	Satisfactorily
E22	17	Male	Much more useful	It is probable	Moderate	Satisfactorily
E23	17	Female	Equally useful	Perhaps	Easy	Well
E24	17	Female	Somewhat less useful	Perhaps	Difficult	Well
E25	16	Male	Equally useful	Perhaps	Easy	Satisfactorily
E26	16	Female	Equally useful	It is probable	Easy	Fairly
E27	17	Female	Somewhat more useful	It is probable	Easy	Satisfactorily
E28	17	Male	Equally useful	Perhaps	Easy	Excellently
E29	16	Female	Equally useful	It is probable	Easy	Satisfactorily
E30	18	Female	Equally useful	Perhaps	Moderate	Fairly
E31	17	Female	Equally useful	Perhaps	Moderate	Satisfactorily
E32	17	Female	Somewhat more useful	It is probable	Moderate	Well
E33	16	Female	Somewhat more useful	It is probable	Easy	Satisfactorily
E34	18	Female	Equally useful	Perhaps	Easy	Well
E35	17	Male	Equally useful	It is improbable	Easy	Satisfactorily
E36	19	Female	Equally useful	Perhaps	Very difficult	Well
E37	17	Female	Somewhat more useful	Perhaps	Moderate	Well
E38	17	Female	Equally useful	Perhaps	Easy	Well
E39	19	Male	Somewhat less useful	It is probable	Moderate	Satisfactorily
E40	18	Female	Somewhat more useful	It is very probable	Easy	Well
E41	17	Female	Somewhat more useful	It is probable	Difficult	Well

E42	18	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E43	17	Female	Somewhat more useful	Perhaps	Easy	Excellently
E44	17	Female	Somewhat less useful	It is improbable	Moderate	Well
E45	19	Female	Somewhat more useful	It is very probable	Moderate	Well
E46	17	Female	Much less useful	It is very improbable	Easy	Well
E47	18	Male	Equally useful	It is probable	Moderate	Satisfactorily
E48	19	Female	Equally useful	It is probable	Very difficult	Fairly
E49	19	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily

Background characteristics of members of control group (n=24), see Subchapter 10.1 for details (please note that member C10, as indicated in the listing with an asterisk (*), provided an unrealistic age of 82 years that we ignored in analysis and thus reliability of also other answers of member C10 should possibly be considered cautiously):

<i>Unique identifier for each member of control group</i>	<i>Age (N/A = not available)</i>	<i>Gender</i>	<i>Response to question: "If you compare to traditional learning from a book, then the method you have tried for adopting knowledge through reading appears to be..."</i>	<i>Response to question: "As a student are you interested in using the method you just tried for adoption of knowledge through reading?"</i>	<i>Response to question "How easy it is for you to adopt new knowledge through reading?"</i>	<i>Response to question "In your opinion, how successfully do you perform at school?"</i>
C1	17	Female	Equally useful	Perhaps	Moderate	Satisfactorily
C2	17	Female	Much less useful	It is very improbable	Moderate	Excellently
C3	18	Female	Equally useful	Perhaps	Easy	Well
C4	17	Female	Somewhat less useful	It is improbable	Moderate	Well
C5	18	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C6	19	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C7	20	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily
C8	19	Female	Equally useful	Perhaps	Moderate	Well
C9	19	Male	Somewhat more useful	It is very probable	Moderate	Satisfactorily
C10 *	N/A *	Male	Equally useful	Perhaps	Moderate	Well
C11	16	Female	Equally useful	It is probable	Easy	Well
C12	17	Male	Much more useful	It is probable	Moderate	Satisfactorily
C13	17	Male	Somewhat more useful	It is probable	Difficult	Well
C14	16	Male	Somewhat more useful	Perhaps	Moderate	Well
C15	17	Male	Somewhat less useful	Perhaps	Easy	Satisfactorily
C16	17	Female	Somewhat more useful	Perhaps	Moderate	Satisfactorily
C17	16	Male	Much more useful	It is very probable	Easy	Satisfactorily
C18	16	Female	Equally useful	It is improbable	Moderate	Well

C19	17	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C20	17	Male	Somewhat less useful	It is very improbable	Very easy	Well
C21	19	Female	Somewhat more useful	It is improbable	Moderate	Satisfactorily
C22	18	Female	Equally useful	It is improbable	Easy	Satisfactorily
C23	17	Female	Somewhat less useful	Perhaps	Difficult	Satisfactorily
C24	19	Male	Somewhat less useful	It is improbable	Moderate	Satisfactorily

Appendix Y

As discussed in Subchapter 10.1 we compared two learning cases by asking an experiment group (n=49) and a control group (n=24) to perform an exploration task.

Exploration task of experiment group

Each member of the experiment group (n=49) was allowed to browse freely following their intuition in the conceptual network for twenty steps and the following listing mentions for each member of experiment group the exploration of twenty steps. This exploration task was carried in “hyperlink network of 55 concepts” (see Appendix J) starting from concept Human.

<i>Unique identifier for each member of experiment group (these identifiers corresponds to those used in Appendix X)</i>	<i>Exploration path of twenty steps</i>
E1	Human->Animal->Nature->Plant->Light->Sun->Plant->Tree->Oxygen->Water->Sea->Water->Travel->Water->Biology->Biology->Nature->Sun->Oxygen->Disease
E2	Human->Health->Disease->Death->Disease->Death->Human->Family->Sibling->Love->Emotion->Happiness->Emotion->Love->Family->Parent->Birth->Animal->Human->Love
E3	Human->Clothing->Religion->Human->House->Home->Family->Child->Adolescence->Education->School->Teacher->Learning->Experience->Learning->Adolescence->Old_age->Death->Disease->Death
E4	Human->Diet_(nutrition)->Health->Biology->Human->Family->Mother->Love->Emotion->Happiness->Emotion->Experience->Emotion->Love->Friendship->Education->Learning->Education->Teacher->Learning
E5	Human->Diet_(nutrition)->Health->Disease->Death->Disease->Death->War->Peace->Education->Learning->Education->Adolescence->Televisio->Adolescence->Human->Love->Happiness->Joy->Happiness
E6	Human->Diet_(nutrition)->Health->Disease->Death->Disease->Death->War->Peace->Education->Learning->Experience->Learning->Education->School->Learning->Teacher->School->Education->Leisure
E7	Human->War->Peace->Education->Learning->Experience->Learning->Education->Adolescence->Old_age->Death->Disease->Death->Heart->Death->Plant->Biology->Organism->Biology->Animal
E8	Human->Health->Diet_(nutrition)->Health->Food->Human->Family->Mother->Love->Emotion->Happiness->Joy->Happiness->Emotion->Experience->Love->Friendship->Adolescence->Education->Learning
E9	Human->Family->Child->Family->Sibling->Love->Emotion->Experience->Emotion->Love->Friendship->Adolescence->Education->Learning->Education->School->Education->Leisure->Work->Leisure
E10	Human->Adolescence->Education->Biology->Animal->Human->Happiness->Emotion->Love->Family->Mother->Parent->Birth->Death->Heart->Organism->Biology->Nature->Oxygen->Water
E11	Human->Family->Mother->Parent->Sibling->Love->Emotion->Experience->Emotion->Happiness->Joy->Happiness->Emotion->Love->Happiness->Biology->Animal->Nature->Organism->Heart
E12	Human->Emotion->Experience->Emotion->Love->Happiness->Emotion->Joy->Happiness->Joy->Happiness->Joy->Emotion->Happiness->Emotion->Love->Friendship->Animal-

	>Nature->Human
E13	Human->Oxygen->Plant->Biology->Human->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Family->Father->Sibling->Sibling->Love->Happiness->Love->Biology
E14	Human->Diet_(nutrition)->Health->Diet_(nutrition)->Organism->Heart->Organism->Biology->Plant->Water->Oxygen->Plant->Nature->Animal->Water->Plant->Tree->Water->Travel->Water
E15	Human->Family->Sibling->Love->Happiness->Emotion->Love->Friendship->Adolescence->Education->Leisure->Televisio->Leisure->Work->Leisure->Mother->Parent->Father->Love->Emotion
E16	Human->Diet_(nutrition)->Organism->Biology->Animal->Nature->Sun->Oxygen->Water->Human->War->Disease->Death->Heart->Death->Plant->Tree->Oxygen->Disease->Oxygen
E17	Human->Diet_(nutrition)->Health->Diet_(nutrition)->Religion->God->Father->Family->Father->Mother->Parent->Mother->Love->Friendship->Animal->Plant->Nature->Oxygen->Sun->Plant
E18	Human->Religion->Sun->Oxygen->Automobile->Oxygen->Sun->Plant->Tree->Oxygen->Plant->Animal->Oxygen->Water->Travel->Plant->Nature->Animal->Nature->Human
E19	Human->Emotion->Love->Emotion->Experience->Emotion->Joy->Happiness->Emotion->Happiness->Joy->Happiness->Emotion->Happiness->Joy->Love->Friendship->Adolescence->Education->School
E20	Human->Diet_(nutrition)->Death->War->Religion->God->Father->Love->Happiness->Emotion->Experience->Emotion->Joy->Happiness->Joy->Joy->Emotion->Love->Friendship->Adolescence
E21	Human->Health->Disease->Death->Organism->Biology->Animal->Organism->Heart->Organism->Plant->Light->Sun->Oxygen->Automobile->Water->Sea->Water->Oxygen->Sun
E22	Human->Diet_(nutrition)->Death->Oxygen->Water->Sea->Water->Sun->Plant->Light->Televisio->Light->Sun->Oxygen->Disease->War->Peace->War->Religion->Sun
E23	Human->Emotion->Happiness->Emotion->Love->Friendship->Love->Family->Mother->Father->Parent->Child->Adolescence->Education->Learning->Learning->Education->Leisure->Work->Leisure
E24	Human->Adolescence->Education->Learning->Education->Adolescence->Televisio->Adolescence->Child->Family->Mother->Parent->Father->Family->Father->Love->Emotion->Joy->Happiness->Emotion
E25	Human->Adolescence->Child->Adolescence->Education->Human->Family->Mother->Father->Love->Family->Sibling->Family->Leisure->Work->Education->Teacher->Learning->Education->Learning
E26	Human->Diet_(nutrition)->Health->Disease->Death->Heart->Death->Human->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Happiness->Emotion->Joy->Emotion->Love
E27	Human->Diet_(nutrition)->Health->Disease->Death->War->Peace->Education->Leisure->Family->Child->Adolescence->Education->School->Education->Love->Happiness->Joy->Happiness->Emotion
E28	Human->Religion->Human->Emotion->Experience->Emotion->Happiness->Joy->Happiness->Emotion->Joy->Emotion->Love->Friendship->Adolescence->Parent->Human->War->Peace->Education
E29	Human->Religion->Human->War->Disease->Death->Disease->Death->Organism->Biology->Nature->Plant->Oxygen->Water->Sea->Sun->Plant->Tree->Oxygen->Heart
E30	Human->Emotion->Experience->Emotion->Love->Family->Leisure->Family->Child->Family->Mother->Family->Father->Family->Sibling->Human->Diet_(nutrition)->Organism->Plant->Nature
E31	Human->Diet_(nutrition)->Health->Biology->Health->Disease->Death->Human->Adolescence->Education->Learning->Education->School->Teacher->Learning->Learning->Teacher->School->Education->Human
E32	Human->Adolescence->Old_age->Adolescence->Televisio->Adolescence->Child->Family->Child->Leisure->Family->Mother->Parent->Human->Health->Death->Human->Family->Leisure->Sibling
E33	Human->Diet_(nutrition)->Health->Biology->Animal->Human->Happiness->Joy->Happiness->Emotion->Love->Friendship->Adolescence->Education->Learning->Learning->Education->Leisure->Sibling->Family
E34	Human->Emotion->Experience->Emotion->Love->Happiness->Emotion->Joy->Happiness->Joy->Happiness->Joy->Emotion->Happiness->Emotion->Love->Biology->Organism->Biology->Human

E35	Human->Diet_(nutrition)->Organism->Heart->Organism->Biology->Health->Diet_(nutrition)->Death->Human->Health->Disease->Death->War->Peace->School->Teacher->Education->Human->Music
E36	Human->Happiness->Emotion->Love->Family->Leisure->Work->Leisure->Education->Adolescence->Child->Old_age->Death->War->Disease->Heart->Death->Disease->Death->Human
E37	Human->Adolescence->Child->Parent->Birth->Animal->Organism->Biology->Organism->Heart->Organism->Plant->Organism->Plant->Light->Oxygen->Plant->Animal->Human->Clothing
E38	Human->Adolescence->Child->Family->Mother->Parent->Birth->Animal->Organism->Biology->Nature->Organism->Plant->Water->Sea->Oxygen->Plant->Organism->Heart->Organism
E39	Human->Diet_(nutrition)->Organism->Biology->Nature->Human->Oxygen->Water->Biology->Organism->Plant->Water->Sea->Water->Plant->Sun->Plant->Tree->Water->Sun
E40	Human->House->Home->Family->Sibling->Parent->Birth->Mother->Love->Happiness->Emotion->Experience->Emotion->Joy->Happiness->Happiness->Joy->Emotion->Love->Friendship
E41	Human->Adolescence->Education->Learning->Education->Teacher->School->Education->Adolescence->Child->Family->Mother->Love->Emotion->Joy->Emotion->Love->Friendship->Adolescence->Old_age
E42	Human->Love->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Friendship->Love->Family->Child->Parent->Human->Televisio->Clothing->Religion->God->Father
E43	Human->Health->Disease->Death->Organism->Biology->Nature->Human->Happiness->Emotion->Experience->Emotion->Love->Biology->Human->Health->Biology->Plant->Light->Televisio
E44	Human->Diet_(nutrition)->Organism->Biology->Nature->Plant->Oxygen->Water->Sea->Water->Plant->Tree->Oxygen->Plant->Nature->Human->Health->Disease->Death->Disease
E45	Human->War->Religion->God->Father->Parent->Child->Adolescence->Education->Learning->Education->Teacher->Learning->Experience->Learning->School->Education->Biology->Organism->Heart
E46	Human->Diet_(nutrition)->Health->Biology->Nature->Organism->Biology->Human->Family->Sibling->Love->Friendship->Adolescence->Education->Learning->Learning->Education->Human->Emotion->Experience
E47	Human->Diet_(nutrition)->Health->Disease->Death->Organism->Heart->Organism->Biology->Animal->Human->Adolescence->Child->Parent->Human->Experience->Emotion->Joy->Happiness->Joy
E48	Human->Health->Disease->Death->War->Peace->War->Religion->God->Father->Love->Happiness->Joy->Happiness->Emotion->Emotion->Happiness->Emotion->Love->Friendship
E49	Human->Emotion->Experience->Emotion->Joy->Happiness->Emotion->Love->Biology->Nature->Sun->Plant->Organism->Biology->Organism->Nature->Animal->Nature->Oxygen->Heart

Following list mentions for each member of the experiment group (n=49) recalled concepts. Here concepts supplied with an asterisk (*) belong to concepts that have been actively selected by student during exploration task and other concepts have been just shown to student during exploration task.

<i>Unique identifier for each member of experiment group (these identifiers corresponds to those used in Appendix X)</i>	<i>Recalled concepts (concepts supplied with an asterisk (*) belong to concepts that have been actively selected by student)</i>
E1	Animal*; Biology; Disease*; Human; Organism*; Oxygen; Plant; Sea*; Sun; Travel*; Tree*; Water;
E2	Animal*; Death; Disease; Emotion; Family; Father; God; Happiness*; Human; Love; Mother*; Religion; Sibling*;
E3	Adolescence; Child*; Death; Disease*; Education; Family*; Home*; House*; Human*; Religion*; School*; Teacher*; Television;
E4	Biology*; Education; Family*; Father; Happiness*; Joy; Love; Mother*; Organism; School; Sibling;
E5	Adolescence; Diet_(nutrition)*; Family; Happiness; Health*; Joy*; Love*; Old_age; Peace*; War*;
E6	Disease; Education; Health*; Human; Learning; Peace*; School; Teacher; War*;
E7	Adolescence*; Animal*; Biology; Child; Death; Disease*; Heart*; Human; Old_age*; Organism*; Oxygen*; Peace*; Plant*; Tree; War*; Water;
E8	Adolescence*; Biology; Diet_(nutrition)*; Education*; Emotion; Family*; Friendship*; Happiness; Health; Human*; Joy*; Love; Mother*; School;
E9	Adolescence*; Biology; Child*; Diet_(nutrition); Education; Emotion; Experience*; Family; Father; Human; Joy; Learning*; Leisure; Love; Mother; Oxygen; School*; Sibling*; Teacher*; Television; Work*;
E10	Biology; Birth*; Death; Emotion*; Father; Happiness*; Heart*; Human*; Love*; Mother*; Nature*; Organism*; Oxygen*; Parent*; Plant; Sibling; Sun; Water*;
E11	Family*; Happiness; Joy*; Love; Mother*; Nature*; Organism*;
E12	Animal*; Biology; Emotion; Friendship*; Happiness; Joy; Love; Nature*; Oxygen; Plant; Religion;
E13	Adolescence; Biology; Emotion; Father*; Happiness; Joy*; Love; Sibling;
E14	Animal*; Biology*; Human; Organism; Travel*; Tree*; Water;
E15	Biology; Education*; Emotion; Family; Father*; Friendship*; Happiness*; Health; Joy; Leisure; Love; Mother*; Religion; Sibling*; Work*;
E16	Animal*; Biology*; Death; Disease; Human*; Organism; Oxygen; Plant*; Sun*; Tree*; Water*;
E17	Animal*; Father; Food; God*; Health*; Mother; Nature*; Plant; Religion*; Sun*;
E18	Animal; Automobile*; Biology; God; Light; Oxygen; Sun; Travel*; Tree*; Water;
E19	Adolescence*; Education*; Emotion; Family; Happiness; Human; Joy; Leisure; Love; School*; Teacher;
E20	Adolescence*; Death*; Diet_(nutrition)*; Disease; Emotion; Family; Father*; Friendship*; God*; Happiness; Human; Joy; Love; Mother; Oxygen; Peace; War*;
E21	Automobile*; Biology*; Heart*; Human; Organism; Oxygen; Plant*; Sea*; Sun; Water;
E22	Death; Disease*; God; Oxygen; Peace*; Religion*; War; Water;
E23	Birth; Education; Emotion; Experience*; Family*; Father*; Happiness*; Joy; Learning; Leisure; Love; Mother*; Sibling; Television; Work*;
E24	Emotion; Family; Father; Joy*; Love*; Mother; Parent*;
E25	Biology; Education; Father*; Leisure; Mother*; School; Sibling*; Teacher*; Television;
E26	Emotion; Happiness; Human*; Joy; Love;
E27	Adolescence*; Death*; Emotion*; Family*; Happiness; Health*; Leisure*; Love*; Peace*; School*; Sibling*; War*;
E28	Child*; Emotion; Happiness; Human; Joy; Parent*; Peace*; Religion*; War*;
E29	Biology*; Death; Disease; Emotion; God; Heart*; Love; Organism*; Oxygen; Plant; Religion*; Sun*; Tree*; War*; Water;
E30	
E31	Adolescence*; Child; Education; Family; Human; Learning; Old_age; School; Teacher;

E32	Adolescence; Death*; Disease*; Family; Health*; Human; Leisure; Old_age*;
E33	Animal*; Biology*; Education; Emotion*; Family*; Friendship*; Happiness; Human*; Joy*; Learning; Love*; Sibling*;
E34	Animal; Biology; Emotion; Family; Friendship; Happiness; Health; Heart; Human*; Joy; Love; Nature; Organism*; Plant;
E35	Biology*; Education; Food; Health; Human; Music*; Organism; Peace*; School*; Teacher*; War*;
E36	Adolescence*; Child*; Death; Diet_(nutrition); Disease; Emotion*; Family*; God; Health; Human*; Music; Old_age*; Religion; Sibling;
E37	Animal; Clothing*; Human*;
E38	Child*; Father; Heart*; Human; Mother*; Nature*; Organism; Oxygen*; Parent*; Plant; Sea*; Sibling; Sun; Tree; Water;
E39	Biology; Human*; Organism; Oxygen*; Plant; Sea*; Sun; Tree*; Water;
E40	Birth*; Emotion; Family*; Father; Friendship*; Happiness; Home*; House*; Joy; Love; Mother*; Sibling*;
E41	Adolescence; Child*; Education; Family*; Friendship*; Happiness*; Joy*; Learning*; Love; Mother*; Old_age*; School*; Teacher*;
E42	Emotion; Family*; Father*; God*; Happiness; Love;
E43	Adolescence; Animal; Biology; Diet_(nutrition)*; Emotion; Happiness*; Health; Human; Light*; Music; Old_age; Organism*; Religion; Sun; Television*;
E44	Animal*; Death*; Disease; Health*; Heart; Human*; Nature; Organism*; Oxygen; Plant; Sun; Tree*; War; Water;
E45	Biology*; Child*; Education; Father*; God*; Health; Heart*; Human; Learning; Mother; Old_age; Organism*; Parent*; Peace; Religion*; School*; Teacher; War*;
E46	Adolescence*; Biology; Child; Education; Emotion*; Family*; Father; Love*; Mother; Old_age; Organism*; School; Sibling*; Teacher; Television;
E47	Adolescence*; Animal*; Biology*; Emotion; Family; Human; Joy; Old_age; Organism; Parent*; Religion;
E48	Death*; Emotion; Family; Father*; Friendship*; God*; Joy*; Love; Mother; Nature; Religion*;
E49	Animal*; Emotion; Experience*; Happiness*; Heart*; Love*; Nature; Organism; Oxygen*; Plant; Sun*;

Exploration task of control group

During exploration task of control group originally 42 unique concepts were shown to each student and when considering repeated exposure of some concepts for control group originally on average 148 concepts were shown to each student meaning originally on average 3.52 occurrences of each unique concept. As explained in Subchapter 10.1, to make conceptual exposure of experiment group and control group more matching to enable more reliable comparison about process of exploration tasks and suggested educational benefits gained with these exploration tasks we decided in following analysis to consider for control group only conceptual exposure concerning 34 most occurring concepts in exploration tasks of control group (when excluding eight concepts there were concepts having shared number of occurrences and here excluded concepts were selected in decreasing alphabetic order). Thus following analysis relies on such observation that during exploration task of control group (24 persons) 34 unique concepts were shown to each student and after the experiment student could recall on average 11.21 unique concepts (about 33.0 percent) of them. When considering repeated exposure of some concepts for control group on average 137 concepts were shown to each student of meaning on average 4.03 occurrences of each unique concept.

When we decided in the following analysis to consider for control group only conceptual exposure concerning 34 most occurring concepts in exploration tasks of control group the original set of 42 concepts with occurrences in parenthesis were: Biology (10), Oxygen (9), Human (8), Organism (8), Adolescence (7), Family (7), Leisure (6), Sibling (6), Animal (5), Child (5), Plant (5), Diet_(nutrition) (4), Old_age (4), Sun (4), War (4), Water (4), Disease (3), Emotion (3), Happiness (3), Heart (3), Religion (3), Clothing (2), Education (2), Father (2), God (2), Health (2), House (2), Learning (2), Light (2), Love (2), Mother (2), Music (2), Parent (2), School (2), Sea (2), Teacher

(2), Tree (2), Automobile (1), Death (1), Friendship (1), Nature (1) and Travel (1). In the following analysis to consider for control group only conceptual exposure concerning 34 concepts we excluded these eight concepts: Sea, Teacher, Tree, Automobile, Death, Friendship, Nature and Travel (for concepts having shared number of occurrences (two occurrences) we excluded concepts in decreasing alphabetic order).

Following list mentions for each member of the control group (n=24) recalled concepts among all 42 unique concepts that were originally shown to each student. Here concepts supplied with an asterisk (*) belong to the original set of 42 unique concepts but do not belong to the final more limited set of 34 unique concepts, and thus concept not supplied with an asterisk (*) belong to the set of 34 unique concepts that were used in our further analysis as discussed in Subchapter 10.1.

<i>Unique identifier for each member of control group (these identifiers corresponds to those used in Appendix X)</i>	<i>Recalled concepts (concepts supplied with an asterisk (*) belong to the original set of 42 unique concepts but do not belong to the final more limited set of 34 unique concepts, and thus concept not supplied with an asterisk (*) belong to the set of 34 unique concepts that were used in our further analysis)</i>
C1	Adolescence; Animal; Biology; Education; Father; Leisure; Mother; Music; Old_age; Organism; Oxygen; Sibling; Sun; War; Water;
C2	Adolescence; Animal; Biology; Child; Diet_(nutrition); Father; Happiness; Health; Learning; Mother; Old_age; Organism; Oxygen; Plant; Religion; School; Sea*; Sibling; Sun; War;
C3	Adolescence; Animal; Diet_(nutrition); Emotion; Father; Friendship*; God; Leisure; Love; Mother; Old_age; Organism; Religion; Sibling; Sun; Water;
C4	Adolescence; Animal; Father; Human; Mother; Old_age; Organism; Oxygen; Parent; Plant; Sibling;
C5	Adolescence; Child; Family; Father; Leisure; Mother; Old_age; Oxygen; Religion; War; Water;
C6	Biology; Child; Education; Family; Father; Human; Learning; Mother; Nature*; Oxygen;
C7	Adolescence; Diet_(nutrition); Father; Human; Leisure; Mother; Old_age; Organism; Oxygen; Sibling;
C8	Biology; Child; Diet_(nutrition); Emotion; Human; Old_age; Organism; Religion;
C9	Adolescence; Automobile*; Biology; Child; Clothing; Diet_(nutrition); Heart; Learning; Organism; Oxygen;
C10	Automobile*; Biology; Child; Happiness; Heart; Learning; Leisure; Light; Organism; Oxygen; Tree*;
C11	Animal; Biology; Child; Death*; Education; Family; Father; Happiness; Leisure; Mother; Organism; Oxygen; Tree*;
C12	Death*; Diet_(nutrition); Family; Health; Leisure; Old_age; Religion; War; Water;
C13	Biology; Diet_(nutrition); Father; Happiness; Health; Heart; House; Human; Love; Mother; Music; Organism; Oxygen; Plant; Religion; Sea*; Sibling; Tree*;
C14	Clothing; Death*; Family; Health; Oxygen; Water;
C15	Adolescence; Animal; Death*; God; Human; Love; Old_age; Oxygen; Religion; War; Water;
C16	Biology; Emotion; Father; Leisure; Love; Mother; Organism; Sibling; Sun; War;
C17	Biology; Child; Father; Human; Mother; Oxygen; Plant; Religion; School; Sibling;
C18	Adolescence; Animal; Child; Death*; Diet_(nutrition); Emotion; Father; Leisure; Mother; Music; Old_age; Oxygen; Sibling; Water;
C19	Adolescence; Biology; Death*; Father; Learning; Leisure; Mother; Sibling;
C20	Adolescence; Animal; Biology; Child; Family; Father; Mother; Old_age; Organism; Oxygen; Religion; Sibling;
C21	Adolescence; Child; Diet_(nutrition); Emotion; Father; Health; Learning; Leisure; Light; Mother; Music; Old_age; Organism; Religion; School; Sibling; War;
C22	Animal; Death*; Diet_(nutrition); Family; Father; Leisure; Mother; Organism; Oxygen; Plant;

	Sibling; War; Water;
C23	Adolescence; Child; Death*; Diet_(nutrition); Education; Family; Home; Human; Nature*; Old_age; Sibling; War; Water;
C24	Adolescence; Death*; Family; Father; Health; Heart; Mother; Old_age; Organism; Oxygen; Sibling; War; Water;

Appendix Z

Based on exploration task of experiment group (n=49), as discussed in Subchapter 10.1, this listing enables comparison of 55 concepts of “hyperlink network of 55 concepts” between number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during exploration and number of unique recalled concepts in respect to hypelinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration.

This listing can be contrasted with Table 10.9 that shows comparison of 55 concepts of “hyperlink network of 55 concepts” between number of times hyperlinked concepts are shown to student during exploration, number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) concepts during exploration.

Number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique recalled concepts in respect to hypelinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)		
<i>Concept</i>	<i>Number of unique recalled selected concepts by all students</i>	<i>Average number of unique recalled selected concepts per each student</i>	<i>Concept</i>	<i>Number of unique recalled selected concepts by all students</i>	<i>Average number of unique recalled selected concepts per each student</i>
Emotion	24	0.489795918	Human	28	0.571428571
Love	24	0.489795918	Emotion	25	0.510204082
Happiness	22	0.448979592	Love	25	0.510204082
Human	18	0.367346939	Family	24	0.489795918
Organism	18	0.367346939	Biology	23	0.469387755
Biology	17	0.346938776	Happiness	22	0.448979592
Family	17	0.346938776	Joy	20	0.408163265
Joy	16	0.326530612	Organism	19	0.387755102
Education	15	0.306122449	Mother	18	0.367346939
Adolescence	14	0.285714286	Father	17	0.346938776
Animal	13	0.265306122	Adolescence	16	0.326530612
Death	13	0.265306122	Animal	15	0.306122449
Mother	13	0.265306122	Education	15	0.306122449
Oxygen	12	0.244897959	Oxygen	15	0.306122449
Disease	11	0.224489796	Sibling	14	0.285714286
Water	11	0.224489796	Death	13	0.265306122
Father	10	0.204081633	Health	13	0.265306122
Plant	10	0.204081633	Plant	13	0.265306122
War	10	0.204081633	Religion	13	0.265306122
Health	9	0.183673469	School	13	0.265306122
School	9	0.183673469	Disease	12	0.244897959
Sibling	9	0.183673469	Sun	12	0.244897959
Friendship	8	0.163265306	Water	12	0.244897959
Sun	8	0.163265306	War	11	0.224489796
Teacher	8	0.163265306	Child	10	0.204081633
Child	7	0.142857143	God	10	0.204081633
Heart	7	0.142857143	Old_age	10	0.204081633
Learning	7	0.142857143	Teacher	10	0.204081633
Nature	7	0.142857143	Friendship	9	0.183673469
Peace	7	0.142857143	Heart	9	0.183673469
Religion	7	0.142857143	Nature	9	0.183673469
Tree	7	0.142857143	Peace	9	0.183673469
Leisure	6	0.12244898	Tree	9	0.183673469
Parent	6	0.12244898	Learning	7	0.142857143
God	5	0.102040816	Leisure	7	0.142857143
Diet_(nutrition)	4	0.081632653	Diet_(nutrition)	6	0.12244898
Old_age	4	0.081632653	Parent	6	0.12244898
Sea	4	0.081632653	Televisio	6	0.12244898
Experience	3	0.06122449	Sea	4	0.081632653

Travel	3	0.06122449	Birth	3	0.06122449
Work	3	0.06122449	Experience	3	0.06122449
Automobile	2	0.040816327	Music	3	0.06122449
Birth	2	0.040816327	Travel	3	0.06122449
Home	2	0.040816327	Work	3	0.06122449
House	2	0.040816327	Automobile	2	0.040816327
Clothing	1	0.020408163	Food	2	0.040816327
Light	1	0.020408163	Home	2	0.040816327
Music	1	0.020408163	House	2	0.040816327
Television	1	0.020408163	Light	2	0.040816327
Cat	0	0	Clothing	1	0.020408163
Computer	0	0	Cat	0	0
Dog	0	0	Computer	0	0
Food	0	0	Dog	0	0
Pet	0	0	Pet	0	0
Telephone	0	0	Telephone	0	0

Appendix AA

As discussed in Subchapter 11.2, this listing shows unique nouns we retrieved in June-July 2013 from cumulative vocabularies of English Vocabulary Profile for six language ability levels (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A): A1 (305 nouns), A2 (880 nouns), B1 (1761 nouns), B2 (2707 nouns), C1 (3198 nouns) and C2 (3710 nouns).

In contrast with Appendix AB, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies.

Language ability level A1 (305 nouns):

address; adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; band; bank; bar; basketball; bath; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; bottom; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; cinema; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; date; daughter; day; december; desk; dictionary; dining room; dinner; doctor; dog; doll; dollar; door; dress; drink; driver; dvd; ear; egg; email; end; evening; example; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; job; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; orange; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plane; plant; plate; player; potato; problem; quarter; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; sentence; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; subject; sugar; summer; sun; sunday; supermarket; swimming pool; table; taxi; tea; teacher; television; tennis; test; the internet; thing; thursday; ticket; time; today; toilet; tomato; tomorrow; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; waitress; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; work; world; writing; year; zoo;

Language ability level A2 (880 nouns):

accident; activity; actor; adjective; adventure; adverb; advertisement; advice; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; armchair; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; battery; bean; bear; beginner; beginning; belt; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; bookshop; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; burger; bus station; bus stop; businessman; businesswoman; calendar; call; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; centre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; chilli; church; cigarette; circle; classmate; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; colleague; college; comb; comic; company; comparative; competition; concert; contact; cook; cooker; cooking; corner; cost; countryside; cousin; cream; cricket; crisp; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; delay; dentist; department; department store; desert; dessert; diary; difference; digital camera; dinosaur; diploma; directions; disco; discount; dish; document; dr; drawer; drawing; dream; driving licence; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; fan; farmer; fashion; fast food; field; file; finger; fire; first name; fishing; flight; fog; folder; footballer; forest; fork; form; fridge; furniture; garage; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guest; guide; guidebook; guy; hall; ham; handbag; headache; headteacher; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id; id card; idea; identification; information; insect; instrument;

invitation; island; it; jam; jazz; jewellery; journey; jumper; keyboard; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; lamp; laptop; leather; left; lemon; lemonade; level; library; licence; lift; light; line; lion; list; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; maths; mechanic; medicine; meeting; melon; member; memory; menu; metre; midway; midnight; mineral water; mirror; mistake; model; moment; monkey; mosque; motorbike; motorway; mountain; mouse; mp3 player; ms; mug; mushroom; nature; neck; necklace; neighbour; news; noon; north; notebook; notice; noun; nurse; occupation; offer; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; path; pc; pear; pence; penfriend; pepper; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pilot; pink; plan; plastic; platform; play; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; pound; practice; present; price; printer; prize; program; programme; project; pub; pupil; purple; purse; puzzle; queen; quiz; rabbit; race; racket; railway; raincoat; rap; rat; reason; receipt; receptionist; red; rent; rest; right; ring; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; salesperson; sauce; sausage; scarf; schoolchild; science; scissors; scooter; screen; seat; second; secretary; set; shampoo; shelf; ship; shop assistant; shorts; show; side; sightseeing; sign; silver; singer; singing; singular; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; slice; snack; snake; snowboarding; soap; sock; sofa; soft drink; software; song; sort; soul; sound; south; space; speaker; spelling; spoon; sports centre; spring; square; stadium; staff; stage; stairs; stamp; star; steak; stomach; stomach ache; storm; story; suit; suitcase; sunglasses; superlative; supper; surfing; surname; surprise; sweater; sweet; sweets; swim; swimming; swimming costume; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tie; tights; timetable; toast; toe; tonight; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; trainer; tram; trip; tune; type; tyre; umbrella; uncle; uniform; use; walk; walking; wallet; war; wash; washing machine; washing-up; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; visitor; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Language ability level B1 (1761 nouns):

ability; accent; access; accommodation; account; accountant; ache; achievement; act; action; ad; admission; advantage; advert; agency; ages; aim; air conditioning; air force; airline; alarm; alphabet; ambition; amount; angel; animation; ankle; anniversary; announcement; ant; antique; apology; appearance; application; architect; architecture; argument; arrangement; arrival; article; aspirin; assistant; athlete; athletics; atmosphere; attack; attention; attitude; attraction; audience; author; average; babysitter; backache; background; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; barman; basin; basket; battle; bay; beauty; bee; beef; behaviour; bell; benefit; bin; biography; birth; block; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; builder; bull; bunch; butcher; butterfly; button; buyer; cab; cabbage; cabin; cable; cage; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; canteen; captain; care; career; cashpoint; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; certificate; challenge; champion; championship; chance; chapter; character; charge; charity; chat show; check; check-in (counter); check-in (desk); checkout; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; composition; conclusion; condition; conference; connection; consonant; contents; contest; continent; contract; copy; corn; correction; cottage; cotton; cough; count; couple; courgette; court; cover; crash; creature; credit; crew; crime; criminal; crop; crossing; cruise; cry; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; decrease; defeat; defence; definite article; delivery; demand; departure; deposit; depth; description; design; designer; destination; detail; detective; development; diagram; diet; difficulty; direction; director; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; display; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earache; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; entry; equipment; essay; event; examiner; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extra; extreme sports; facilities; fair; fall; fare; farming; favour; favourite; fear; fee; feeling; ferry; festival; fever; fiction; fifth; fight; figure; film-maker; final; fine; finish; fire station; firefighter; firework; firm; fitness; flag; flavour; flood; flour; flu; flute; fly; folk; fool; forecast; forehead; foreigner; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; gap; generation; ghost; giraffe; go; goalkeeper; goat; goods; government; grade; grant; graphics; greeting; grill; groom; ground; guard; guess; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; hairdryer; handball; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hit; hole; honeymoon; hope; hostel; housework; hug; human; hunger; hurry; hut; ice hockey; ice skating; identity card; illness; imagination; immigration; importance; improvement; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interval; interview; invention; iron; ironing; issue; item; jail; jar; jet; jogging; joke;

journalist; judge; jug; jump; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knickers; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; league; lecture; leisure; length; lettuce; lie; lighter; lightning; limit; link; lip; liquid; literature; loan; location; lock; logo; look; lorry; lottery; love; lover; luxury; madam; mall; marriage; mate; material; maximum; meaning; membership; mess; message board; metal; method; mile; millimetre; mind; minimum; mix; modal (verb); monster; monument; mood; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; net; niece; nightclub; nightlife; nightmare; northeast; northwest; noticeboard; novel; object; occasion; ocean; officer; olive; operation; opinion; opportunity; opposite; option; orchestra; organization; oven; owner; packet; palace; pan; pants; paragraph; parcel; parking; parrot; pass; password; patient; pattern; pavement; pay; pea; peace; peach; peak; peanut; pedestrian; penguin; penny; performance; performer; period; permission; pharmacy; photocopy; phrasal verb; phrase; pie; pile; pill; pin; pineapple; pipe; pirate; planet; pleasure; plug; pocket money; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; position; possibility; postman; pot; powder; power; prayer; preparation; preposition; prescription; presentation; president; priest; primary school; prince; princess; prison; prisoner; product; profession; professor; progress; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quality; quantity; question mark; questionnaire; queue; rail; rainforest; range; reader; reception; recipe; record; recording; recycling; refreshments; refund; region; registration; relation; relationship; relative; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; reservation; resort; respect; result; return; reward; review; revision; ride; rider; robot; role; roll; romance; rose; route; routine; row; rubbish; rug; ruin; rule; run; sailor; salary; salesman; saleswoman; salmon; sand; sandal; saucepan; saucer; scene; scenery; science fiction; scientist; score; scream; sculpture; search; season; secondary school; secret; section; security; seller; sense; series; server; service; session; sex; shade; shadow; shape; shark; sheet; shock; shore; shoulder; shout; sight; signature; signpost; silence; silk; single; sir; situation; ski; skill; skin; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; southwest; souvenir; speech; speed; spice; spider; spinach; spot; spy; squash; stall; start; statue; stay; step; stick; stone; store; stranger; strawberry; stream; stress; strike; stripe; studio; study; stuff; style; success; suggestion; sum; sunrise; sunset; sunshine; support; supporter; sweatshirt; swimmer; switch; system; tablet; takeaway; talent; talk; tap; taste; tax; teaching; tear; technique; technology; temple; tense; tent; thank you; the first floor; the ground floor; the seaside; thief; thought; thriller; throat; thumb; thunder; tick; tiger; tin; tip; tissue; title; tongue; toothpaste; topic; total; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; traveller; trend; trick; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; union; unit; user; wage; valley; value; van; wardrobe; variety; warning; vase; waste; waterfall; wave; weather forecast; web; webcam; wedding; vegetarian; vehicle; weight; welcome; vet; whale; wheelchair; video clip; wildlife; windscreen; windsurfing; wing; virus; visa; visit; voice; volume; workout; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Language ability level B2 (2707 nouns):

absence; abuse; accuracy; acid; addict; addiction; addition; adjustment; admiration; adoption; advance; advertising; affair; affection; agent; agreement; agriculture; aircraft; alternative; aluminium; amazement; ambassador; amusement; analysis; analyst; ancestor; anger; anxiety; apostrophe; appeal; appreciation; approach; approval; arrest; arrow; aspect; assessment; assistance; association; astonishment; atom; attachment; attempt; aubergine; authority; availability; award; backup; badge; bakery; balance; ban; bang; banker; banking; bargain; barrier; base; basement; basis; beam; beat; belief; belongings; bench; bend; berry; bestseller; bikini; billion; bite; blade; blame; bomber; bombing; bond; bonus; booklet; bookmark; boost; bow; bra; bracket; brand; bravery; breakdown; breakthrough; breed; brick; broadband; brother-in-law; browser; bruise; budget; bulb; bullet; bumper; bun; burglar; burglary; bush; cabinet; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; cardboard; cardigan; carelessness; carnival; cast; catalogue; category; catering; cause; cell; cellar; cello; cemetery; centigrade; certainty; chaos; characteristic; charm; chart; chemical; cherry; chest; chief; chimney; choir; circumstance; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collapse; collector; collocation; colon; column; combination; comedian; comfort; command; commerce; commercial; commitment; committee; community; companion; comparison; composer; compromise; concentration; concept; concern; concrete; conductor; confession; confidence; confirmation; conflict; confusion; conjunction; consciousness; consequence; conservation; consideration; construction; consultant; consumer; container; content; context; contrast; contribution; control; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; crossroads; cruelty; cure; curiosity; cursor; curve; cycle; darkness; darling; dash; data; database; daughter-in-law; dawn; daylight; daytime; deadline; deal; dealer; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; defender; definition; delight; democracy; demonstration; denim; depression; desire; desktop; despair; destruction; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disappearance; disaster; discipline; discovery; disgrace; disguise; dishonesty; dislike; disposal; dissatisfaction; distinction; dive; division;

donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; ease; economist; economy; edition; editor; efficiency; electrician; electronics; element; embarrassment; emotion; emphasis; encouragement; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; equality; era; error; escalator; escape; estate; estimate; evidence; evil; evolution; exception; exclamation mark; exhaustion; existence; expansion; expectation; expense; explosion; export; expression; extension; extent; extract; eyebrow; eyelash; eyelid; eyesight; facility; factor; failure; faith; fame; fantasy; fat; fate; father-in-law; fault; feather; feature; feedback; female; fence; fighting; finance; fingernail; fire brigade; first language; fisherman; flame; flash; flexibility; fluency; force; fortune; fox; freedom; friendliness; frost; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; glance; global warming; god; good; gossip; graduate; graph; grave; greatness; grief; grip; grown-up; growth; guarantee; guidance; guilt; gum; guts; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; helper; highlight; hint; hip; hold; honesty; honour; hood; hook; horn; horror; host; household; human rights; humour; hunting; hyphen; icon; identity; idiom; idiot; image; immigrant; impact; imperative; impression; incident; income; increase; independence; individual; infection; inflation; influence; inhabitant; injury; input; inside; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; interior; interruption; introduction; invasion; inventor; inverted commas; investigation; investigator; investment; investor; involvement; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; kingdom; landing; landlady; landlord; lane; lap; laser; laughter; laundry; layer; laziness; lead; leaflet; leak; learner; learning; lecturer; leek; legend; leopard; liar; liberty; lid; lifestyle; lifetime; lighting; litter; liver; living; load; loaf; lobby; loss; loyalty; lung; lyrics; maintenance; majority; maker; male; management; mankind; manner; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; means; measure; measurement; medal; mention; microphone; mine; minister; minority; mint; miracle; misery; mission; mist; misunderstanding; mixture; monitor; moonlight; mother-in-law; motivation; motive; motor; motorist; movement; mud; muscle; musical; myth; nail; nation; native speaker; navy; need; needle; nerves; network; nonsense; novelist; nuisance; nursery; nut; oak; objection; objective; obligation; observation; obsession; offence; offender; opening; operator; opponent; organizer; origin; original; outline; outskirts; overtime; owl; oxygen; pace; pack; package; pancake; panic; paperwork; parachute; parade; parliament; partnership; passage; passion; patience; pause; paw; payment; pedal; penalty; pension; percentage; personality; pharmacist; phase; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; plus; point of view; poison; polar bear; policy; politeness; pond; popularity; portion; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presence; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; process; producer; production; professional; profile; profit; programming; promotion; proof; proper; proposal; prospect; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punch; punishment; purchase; pyjamas; quarrel; query; quiet; racism; rage; rainbow; rape; rate; ray; razor; reach; reaction; reality; rebel; recession; recommendation; recovery; recreation; reduction; referee; reference; reflection; refugee; regret; regulation; rehearsal; release; relief; remains; remark; remedy; replacement; representative; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush; rush hour; sadness; safety; sale; salon; sample; satellite; satisfaction; savings; scale; scandal; scar; scent; schedule; scheme; scratch; script; seal; seed; selection; self-confidence; semicolon; semi-final; seminar; sensation; separation; servant; setting; share; shed; shell; shelter; shift; shooting; shopkeeper; shortage; shot; sickness; sigh; signal; similarity; sister-in-law; skeleton; slash; slave; slope; smoker; softness; soil; solo; son-in-law; soundtrack; source; specialist; species; spectator; spirit; splash; sponsor; spray; spread; spreadsheet; stain; standard; state; statement; statistics; steam; steel; steering wheel; stepfather; stepmother; stock; stool; stopover; storage; storey; strain; strategy; strength; string; stroke; structure; struggle; substance; substitute; suburb; subway; suffering; suffix; suicide; summary; sunlight; supplier; supply; surface; surgery; surroundings; survey; survival; survivor; suspect; suspicion; swan; sweat; swing; sword; syllable; symbol; sympathy; symptom; tabloid; tail; tale; tan; target; task; teaspoon; telecommunications; telescope; temper; temptation; tension; terminal; terms; terrace; territory; terror; terrorism; terrorist; thanks; the first person; the last minute; the second person; the third person; theft; theme; theory; therapy; thermometer; thesis; thigh; third; thirst; threat; tide; timing; tiredness; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; transfer; trap; tray; treasure; treatment; trekking; trial; triangle; tribe; trolley; trophy; trunk; trust; truth; try; tutor; understanding; unhappiness; upbringing; update; upgrade; waist; wait; ward; variation; warmth; wasp; weakness; wealth; weapon; welfare; venue; verse; version; wheat; whisky; whistle; victim; victory; widow; width; viewer; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; yell; zebra; zip;

Language ability level C1 (3198 nouns):

abortion; acceptance; accessory; accusation; acquaintance; adaptation; administration; administrator; adviser; agenda; aggression; aid; alert; allegation; allowance; ally; alteration; amateur; amendment; angle; annoyance; appetite; applause; appliance; archaeologist; archaeology; asset; assignment; assumption; assurance; attendance; auction; audition; awareness; avenue; bacteria; beak; bid; blindness; boundary;

brass; bribe; bronze; bubble; bully; bump; burden; campaign; cancellation; capability; capture; carriage; caution; cholesterol; chore; clarification; closeness; clutch; coal; collaboration; commodity; competence; completion; complex; complication; component; congestion; consent; constitution; consumption; contestant; controversy; convention; coolness; corruption; counterpart; coverage; crawl; criterion; cultivation; cutback; daycare; debut; declaration; dedication; deduction; defect; deficiency; deficit; delegate; density; deodorant; deputy; destiny; developer; diesel; digestion; directory; disapproval; discomfort; discontent; discrimination; dismissal; disorder; displacement; disrespect; disruption; dissertation; distraction; distress; distribution; disturbance; diversity; divide; dock; domain; domination; downside; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; equivalent; erosion; establishment; evaluation; exaggeration; excess; executive; exhaust; exhibit; expenses; exploration; exposure; exterior; extinction; extrovert; fabric; fairness; fascination; feast; fibre; flair; flaw; fleet; flow; footstep; format; formula; foundation; friction; fright; fumes; fund; funding; fuss; gadget; gain; garment; gathering; gene; generalization; genius; geology; germ; gerund; gesture; giant; glamour; glimpse; globalization; glory; grace; greed; guideline; habitat; harassment; hardship; hate; hatred; hazard; heading; health care; historian; hospitality; housing; humanity; hunt; hygiene; iceberg; idol; illustration; implication; import; inability; inaccuracy; inclusion; inconvenience; index; indication; industrialization; infrastructure; initiative; injustice; innocence; innovation; insight; inspection; installation; instance; integration; interaction; interference; isolation; itinerary; jargon; jealousy; joint; journal; junk; junk mail; knob; labour; landmark; launch; lawn; layout; leadership; liability; liberation; limitation; listener; literacy; log; logic; loneliness; lounge; machinery; magistrate; mammal; mansion; mat; mechanism; memo; mentality; merit; migration; miner; mining; ministry; misfortune; misuse; mode; modification; move; mustard; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; norm; notion; nutrition; obesity; obstacle; occurrence; odds; opposition; optimist; organ; outcome; outlook; overdraft; overview; ownership; ozone; palm; panel; paradise; participant; pastry; peasant; peer; pensioner; perfection; perk; permit; personnel; perspective; phenomenon; pony; posture; praise; precaution; predator; pregnancy; premises; preservation; prestige; principle; print; privilege; probability; productivity; programmer; progression; projection; proportion; proposition; prosperity; prostitute; protein; provider; provision; pulse; purity; pyramid; radiation; rank; rarity; rating; ratio; readership; readiness; realization; rebellion; reconstruction; recruitment; rectangle; redevelopment; redundancy; refusal; regard; register; reign; relevance; reliability; reminder; renewal; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rip-off; rival; role model; rudeness; runway; sack; sacrifice; saint; saving; scholar; scholarship; scope; sector; self; self-esteem; selfishness; sensitivity; sequence; serial; setback; settlement; sewing; shame; shortcoming; shuttle; shyness; side effect; significance; simplicity; simulation; sketch; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; soya; spam; speciality; specification; spectrum; speculation; sphere; spine; spokesman; spokesperson; sponsorship; stability; staircase; stamina; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; striker; strip; stroll; subsidy; substitution; subtitles; successor; suitability; summit; superior; supervision; supervisor; surge; surgeon; tactic; takeover; tank; teamwork; technician; techno; telly; tendency; texture; the middle class; the upper class; the working class; therapist; thrill; tobacco; token; toll; torture; trainee; transaction; transformation; transportation; trek; triumph; tuition; turnover; twist; uncertainty; unity; unwillingness; usage; usefulness; vacancy; walker; variable; warrior; vegetation; veil; vein; well-being; vest; viewpoint; win; vine; wit; witch; workforce; workplace; workshop; worse; youngster;

Language ability level C2 (3710 nouns):

accumulation; acre; adolescent; advocate; alcoholic; alliance; allocation; ambiguity; analogy; anchor; antibiotic; anticipation; arch; army; artificial intelligence; aspiration; assault; assembly; astronomy; attribute; awe; backing; bark; barn; bet; bias; blackmail; blend; blister; blow; bribery; bundle; bureaucracy; burial; buzz; capitalism; cargo; casserole; casualty; catastrophe; chancellor; chapel; charisma; cheer; cheerfulness; chill; circuit; circulation; civilian; clarity; clash; classification; cliché; closure; clumsiness; coastline; coherence; coldness; combat; comeback; commander; complexion; complexity; compliment; conception; concession; confrontation; conscience; consensus; constraint; consultation; contempt; continuity; contraception; contraceptive; contradiction; conversion; conviction; cookie; coral; core; corpse; counselling; counsellor; coup; crack; crackdown; craving; craziness; credibility; creep; crush; crystal; custody; cutlery; decay; deception; delegation; denial; dependence; deprivation; descendant; desperation; deterrent; devastation; diagnosis; dialect; diarrhoea; dice; dignity; diplomacy; discretion; disgust; dismay; disposable income; disposition; dispute; dna; dominance; donor; doom; doorway; drain; drought; echo; elimination; embrace; empathy; endeavour; endurance; entity; essence; exile; expenditure; explosive; extremist; fake; famine; fanatic; feat; filter; fireplace; fist; flashback; flesh; fluid; focus; follower; forgery; forgiveness; formation; foul; founder; fraction; fragrance; framework; fraud; frenzy; fringe; frontier; frown; fulfilment; fury; gamble; gasp; gaze; glare; glow; glue; goodness; grain; grasp; grin; groan; grounds; gulf; hail; haul; heap; heir; heritage; hesitation; hierarchy; homelessness; horizon; hostage; hostility; humility; hypocrisy; hypothesis; ignorance; illusion; imitation; immune system; impatience; implementation; impossibility; imprisonment; impulse; incentive; inclination; indicator; indifference; individuality; inequality; infancy; infant; inferior; inferiority; influx;

inheritance; inhibition; injection; insecurity; insomnia; instinct; instruction; integrity; intellect; intellectual; intensity; intent; interpretation; intervention; intolerance; introvert; intruder; intrusion; intuition; irony; irritation; justification; kidney; knot; knuckle; lad; leap; leave; legacy; legislation; lifespan; likelihood; linen; loathing; local; loft; longevity; longing; lump; lure; margin; massacre; masterpiece; materialism; materialist; medication; mediocrity; medium; melody; memorial; mercy; merger; metaphor; millennium; mishap; misinterpretation; missile; momentum; monopoly; morale; mortality; motion; muddle; murmur; narrative; narrator; negligence; nerve; nest; normality; nostalgia; nostril; novelty; observer; odour; official; offspring; omission; openness; optimism; ordeal; orientation; ornament; orphan; outbreak; outgoings; outlet; output; outrage; overload; pact; paradigm; paradox; parallel; particle; pastime; patch; peer pressure; perception; perseverance; persistence; persuasion; pioneer; pit; plague; plea; plight; pole; portrayal; practitioner; precedent; predecessor; premium; presumption; prey; proceedings; procession; produce; propaganda; prosecution; prosecutor; protagonist; proverb; province; provocation; proximity; psychiatrist; pursuit; quest; quotation; quote; racist; radical; raid; rally; rash; read; realm; reasoning; reassurance; recognition; recollection; recruit; referendum; reform; refuge; regime; rejection; relish; remorse; repetition; representation; reproach; resemblance; resentment; residence; resignation; resilience; resistance; resolution; resolve; restraint; retailer; retention; retreat; reunion; revelation; reversal; reverse; revival; rhyme; ribbon; riches; ritual; rivalry; roar; round; ruling; saddle; sail; sanction; saying; scan; scarcity; scenario; schooling; scrap; scrutiny; self-assurance; self-awareness; self-control; self-discipline; self-reliance; self-respect; sensibility; sentiment; serenity; severity; shield; sibling; simplification; sin; sincerity; sip; siren; skull; slap; slaughter; snob; socialism; sorrow; spade; spark; specimen; spending; spite; splendour; spotlight; spouse; squad; stable; stance; standpoint; stardom; starvation; stimulus; stitch; strand; strap; stubbornness; stupidity; sufferer; superiority; supplement; surplus; suspense; sustainability; syllabus; synonym; tact; talks; taxpayer; tenant; tenderness; thinker; thread; threshold; throne; timber; toddler; tolerance; toughness; tractor; trader; trait; tranquility; transition; transmission; transplant; trash; trauma; treat; treaty; tribute; trilogy; trio; troops; turmoil; undertaking; unrest; upkeep; urge; vaccination; vaccine; validity; vandalism; vanity; warehouse; weed; velvet; venture; verdict; veteran; whim; vice; wilderness; villager; willpower; virgin; virtue; vitality; withdrawal; vocation; woodland; workaholic; worship; voter; vow; wreck; wreckage; wrinkle; xenophobia;

Appendix AB

As discussed in Subchapter 11.2, this listing shows unique nouns in high-frequency lists we retrieved in June-July 2013 from Oxford Wordlist (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile) for five school levels (<http://www.oxfordwordlist.com/pages/search.asp>): Preparatory (685 nouns), Year 1 (811 nouns), Year 2 (1008 nouns), Year 3 (1412 nouns) and Year 4 (1445 nouns).

In contrast with Appendix AA, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies.

Preparatory (685 nouns):

accident; adventure; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; bath; battle; beach; bear; beat; bed; beginning; bend; bike; bird; birthday; biscuit; bit; bite; black; block; blood; blue; board; boat; bomb; bone; book; boss; bottle; bottom; bowl; box; boy; bra; branch; bread; breakfast; bride; bridge; brother; brush; bubble; builder; bump; bus; bush; butterfly; buzz; cabbage; cake; call; camera; camp; camping; can; candle; car; card; care; case; cash; castle; cat; cave; centre; cereal; certificate; chair; champion; change; channel; chart; check; cheer; cheese; cherry; chess; chicken; chief; child; chocolate; church; circus; city; class; classroom; climbing; clinic; clothes; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; corner; costume; country; couple; court; cousin; cover; crab; crash; crew; cricket; crocodile; cross; crowd; cup; cushion; cut; dad; dance; dancing; dash; day; december; delivery; dentist; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; doctor; dog; doll; dollar; dolphin; door; drawing; dream; dress; drink; drive; drop; duck; dust; dvd; eagle; ear; earth; egg; electricity; elephant; end; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; festival; fight; fighting; final; fine; finger; finish; fire; fish; fishing; flame; flat; floor; flower; flute; fly; food; foot; football; fork; fox; frame; friday; fridge; friend; frog; fruit; fun; game; garage; garden; gardening; gas; gear; ghost; giraffe; girl; glow; glove; go; goal; gold; golf; good; grandma; grass; green; grey; ground; guitar; gum; gun; guy; gymnastics; hair; hall; ham; hand; handball; hat; hate; head; headache; heart; heaven; helicopter; helmet; help; hero; hill; hip; history; hit; hockey; hold; hole; holiday; home; homework; honey; hood; hope; horn; horse; hospital; hotel; house; hunt; hunting; hurry; idea; ink; inside; instrument; island; it; jacket; jail; jam; jazz; jeans; jet; job; juice; jump; june; jungle; kangaroo; kick; kid; killer; killing; kind; king; kingdom; kitchen; kite; kitten; ladder; lake; land; language; left; leg; lemon; leopard; lesson; letter; lettuce; level; library; light; lighter; lightning; line; lion; list; look; lounge; love; lunch; machine; magazine; magic; mall; man; market; mat; match; mate; maths; meal; meat; medal; medicine; metal; milk; mind; mine; miss; model; monday; monkey; monster; morning; mother; motorbike; mouse; move; movie; mr; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; need; net; news; newspaper; night; noise; nose; number; ocean; office; officer; orange; orchestra; order; owner; pack; packet; paint; pair; palace; pancake; pants; paper; parade; parent; park; part; partner; party; pasta; patch; path; peace; pear; pencil; penguin; people; person; pet; phone; photo; picnic; picture; pie; piece; pig; pillow; pin; pineapple; pink; pirate; pit; pizza; place; plan; plane; planet; plant; plate; play; player; playground; poison; pole; police; policeman; pond; pony; pool; power; present; prince; princess; prize; professor; project; pub; puppy; purple; push; queen; question; rabbit; race; radio; rain; rainbow; read; reading; record; rectangle; red; reptile; rescue; restaurant; reward; rice; ride; right; ring; river; road; roar; robot; rock; rocket; roll; roof; room; rubbish; ruler; run; runner; running; sack; safety; salad; sale; sand; sandwich; saturday; sauce; sausage; saying; school; science; scooter; score; sea; second; secret; section; set; share; shark; shed; sheep; ship; shirt; shoe; shop; shopping; shot; show; shower; side; singing; sink; siren; sister; size; skate; skateboard; skateboarding; skating; skeleton; ski; skiing; sky; sleep; snake; snow; song; sort; sound; soup; space; speed; spelling; spider; sport; spot; spring; stage; stairs; stand; star; start; station; stay; stone; stop; store; storey; storm; story; stranger; street; stretch; study; stuff; sugar; summer; sun; sunday; sweet; swim; swimming; swing; sword; system; table; tail; tale; talk; tan; tap; tea; teacher; team; television; temple; tennis; tent; thanks; theatre; thing; thought; thumb; thunder; thursday; ticket; tie; tiger; timber; time; timetable; today; toe; toilet; tomato; tomorrow; tonight; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; trap; travel; treasure; tree; triangle; trick; trip; trophy; trouble; truck;

tuesday; turn; turning; tv; twist; type; umbrella; uncle; use; walk; walking; wall; war; wash; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; vest; west; vet; whale; wheel; whistle; white; video; will; village; win; wind; window; winner; winter; wish; visit; visitor; witch; voice; volcano; wolf; woman; wood; work; world; worm; wreck; writing; yard; year; yellow; zebra; zoo;

Year 1 (811 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; arrest; art; assembly; athletics; attack; baby; back; background; bacon; bag; ball; ballet; balloon; band; bang; bank; bar; barbecue; barn; base; baseball; basket; basketball; bat; bath; battle; beach; bear; beat; bed; bedroom; bee; beef; beginning; bell; bend; bike; bin; bird; birthday; biscuit; bit; black; blanket; block; blood; blow; blue; boat; body; bonus; book; boss; bottle; bottom; box; boxing; boy; brand; bread; break; breakfast; brother; brown; brush; bubble; bucket; bug; builder; building; bull; bunch; burger; bus; bush; business; butter; butterfly; button; buzz; cabin; cage; cake; call; camel; camping; can; candle; cap; car; card; cardboard; care; carpet; cash; cast; castle; cat; cave; centre; century; cereal; chain; chair; change; chaos; charge; cheese; chemist; chess; chest; chicken; child; chin; chip; chocolate; church; circle; circus; city; class; classroom; climbing; clothes; clown; club; coach; coffee; coin; cold; collar; collection; colour; commercial; competition; complex; computer; concert; contest; cook; cookie; cooking; coral; corner; cost; cottage; cotton; council; count; couple; course; court; cousin; cow; cover; crash; crawl; cream; creature; cricket; crime; criminal; crocodile; cross; crossing; cruise; cry; cucumber; cup; cupboard; cut; cycle; dad; dance; dancer; dancing; danger; darling; day; december; dentist; desert; designer; desk; devil; diamond; diet; dinner; dinosaur; directions; dirt; disco; dive; diving; dock; doctor; dog; doll; dollar; dolphin; donkey; door; dot; drawing; dream; dress; drink; drive; driver; drop; duck; dump; dvd; earth; egg; elephant; emergency; end; ending; engine; eye; face; fact; factory; fake; fall; family; fan; farm; farmer; fashion; fat; father; favourite; field; fifth; fight; fighting; final; fine; finish; fire; fish; fishing; flag; flash; flat; flavour; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garage; garden; gardening; gate; gear; gentleman; ghost; giant; gift; giraffe; girl; glass; glasses; go; goal; goat; god; gold; golf; good; grade; grandma; grandmother; grass; green; grey; ground; group; guess; guitar; gum; gun; guy; gym; gymnastics; hair; haircut; hall; hammer; hand; handle; hat; head; headache; heart; heaven; helicopter; help; hero; hill; hit; hold; hole; holiday; home; homework; honey; honeymoon; honour; hook; hope; horse; hospital; hotel; hour; house; hug; hunting; iceberg; idea; information; inside; instructor; interview; invitation; island; it; jacket; jail; january; jar; jealousy; job; joke; joy; jump; jumper; june; jungle; kangaroo; key; keyboard; kick; kid; killer; killing; kind; king; kiss; kit; kitten; knife; lab; lady; lake; land; lane; lap; laptop; lawn; leader; leaf; leap; learning; leave; left; leg; lemon; leopard; letter; lettuce; level; library; life; light; lightning; line; lion; lip; living; look; lounge; love; lover; lunch; lunchtime; machine; magic; maker; man; march; market; marriage; mask; master; mat; match; mate; maths; matter; meal; means; meat; medal; medicine; memory; mess; message; metal; microphone; midnight; milk; mine; minute; miss; mistake; monday; money; monkey; monster; morning; mosquito; mother; motor; motorbike; mountain; mouse; moustache; mouth; move; movie; mr; mrs; ms; mud; mum; murder; murderer; mushroom; music; musical; name; narrative; nature; neck; need; neighbour; nest; net; night; noise; note; notice; november; number; ocean; opening; orange; oven; owl; owner; packet; paint; painting; pair; palace; pan; pants; paper; parcel; parent; park; part; party; pass; pastry; patch; pay; pen; pencil; penguin; people; performance; person; pet; phone; photographer; picnic; picture; piece; pig; pile; pink; pipe; pirate; pizza; place; plan; plane; planet; plate; play; player; playground; pocket; point; poison; pole; police; pond; pony; pool; pop; port; post; postman; potato; pound; power; practice; prawn; present; prince; princess; principal; print; printer; prize; problem; proper; pub; puppy; purple; push; pyjamas; quarter; queen; quiet; rabbit; race; rain; rainbow; rainforest; rat; reach; read; reading; reason; recycling; red; register; rescue; rest; restaurant; ride; right; ring; river; road; robot; rock; rocket; roll; roof; room; rope; rose; round; row; rule; run; running; safety; sail; salad; sale; sand; sandwich; saturday; sauce; school; science; scooter; score; scream; screen; sea; season; seat; second; secret; september; session; set; sewing; shadow; shape; share; shark; shed; sheep; sheet; shell; ship; shooting; shop; shopping; shot; shout; show; shower; side; silver; singer; singing; single; sink; siren; sister; size; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; snowboarding; son; song; sound; soup; space; speed; spider; sport; spot; spread; stadium; staff; stage; stairs; stand; star; start; stay; step; stick; stop; storm; story; strawberry; street; stretch; strike; stuff; sugar; suitcase; summer; sun; sunday; surprise; sweat; swim; swimmer; swimming; swing; sword; table; tail; takeaway; talk; tank; tap; target; taste; tea; teacher; teaching; team; tennis; tent; test; thanks; thief; thing; third; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tomorrow; tonight; tool; tooth; toothbrush; top; touch; tour; towel; tower; town; toy; track; tractor; train; training; tram; travel; tray; treasure; tree; trick; trophy; trouble; truck; try; tube; tuesday; tunnel; turkey; turn; turning; tv; type; uncle; use; wait; walk; walker; walking; wall; van; war; warehouse; wash; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; version; whale; wheel; whistle; white; wife; wildlife; will; village; win; window; wing; winter; wish; visit; witch; voice; wolf; volleyball; woman; wood; wool; word; work; worker; workshop; world; worst; writing; yard; year; yellow; zoo;

Year 2 (1008 nouns):

ad; adult; adventure; aeroplane; afternoon; age; ages; air; airport; alarm; ambulance; animal; ant; apple;
 argument; arm; army; art; attack; august; baby; back; bacon; badge; bag; ball; balloon; banana; band; bang;
 barbecue; bark; barn; base; basketball; bat; bath; bathroom; battery; battle; bay; beach; beak; bear; beard;
 beat; bed; bedroom; bee; beer; bell; bench; bike; billion; bin; bird; birthday; biscuit; bit; bite; black; blanket;
 block; blood; blow; blue; board; boat; body; bomb; bone; book; boost; boot; border; boss; bottle; bottom;
 bow; bowl; box; boy; boyfriend; bracelet; brain; bread; break; breakfast; breath; breed; bridge; brother;
 brown; brush; bubble; bucket; bug; building; bull; bump; bunch; bus; bush; business; butter; butterfly; buzz;
 cabbage; cabinet; cage; cake; calculator; calf; call; camel; camera; camp; camping; can; cancer; candle;
 canteen; cap; captain; capture; car; card; care; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat;
 cave; cemetery; centre; chain; chair; challenge; chance; change; channel; chapter; chat; check; cheer; chef;
 chess; chest; chicken; chimney; chip; chocolate; choice; church; cinema; circle; city; class; classroom;
 cleaner; climbing; clock; clothes; cloud; clown; club; coach; code; coffee; cold; collar; collection; collector;
 college; colour; community; competition; computer; contact; container; contest; continent; control; cook;
 cookie; cooking; cooperation; coral; corner; cost; cottage; cough; count; counter; country; couple; course;
 court; cousin; cow; cover; crab; craft; crash; cream; creature; credit; crew; cricket; crime; crocodile; cross;
 cruise; cry; crystal; culture; cup; cupboard; curriculum; customer; cut; cutlery; dad; dance; dancing; darling;
 daughter; day; death; december; decision; deck; deer; defeat; desert; desk; dessert; devil; diamond; diary;
 dice; diesel; diet; dimension; dinner; dinosaur; direction; directions; disco; disease; distance; diver; diving;
 doctor; dog; doll; dolphin; donkey; door; download; dr; drawer; drawing; dream; dress; drink; drive; driver;
 drop; drought; duck; dvd; eagle; earth; edge; egg; elephant; end; enemy; engine; episode; escape; evening;
 event; evil; exercise; exhaust; extra; eye; face; factory; fair; fall; family; fan; fantasy; farm; farmer; fat;
 favourite; feeling; fence; ferry; field; fight; fighting; final; fine; fire; fireplace; fish; fishing; fitness; flame; flash;
 flat; flight; flood; floor; flour; fluid; fly; food; foot; football; force; forest; form; fox; frame; freezer; friday; fridge;
 friend; fright; frog; frost; fruit; fuel; fun; funeral; fur; furniture; future; gain; game; gang; gap; garage; garden;
 gardening; gate; gear; gentleman; ghost; giant; gift; giraffe; girl; girlfriend; glass; glasses; glow; glue; go;
 goal; god; gold; golf; good; grade; grandfather; grandma; grandpa; grass; grave; green; grey; ground; group;
 guard; guess; guitar; gun; guts; guy; gymnastics; hair; haircut; ham; hand; handball; handle; harm; hat; hate;
 head; headache; heading; heart; heat; help; hero; hill; hip; history; hit; hobby; hockey; hold; hole; holiday;
 home; homework; honey; hook; hope; horn; horse; hospital; hotel; hour; house; hug; human; hunt; hunting;
 husband; hut; ice; idea; imagination; inch; insect; inside; instructor; interaction; island; it; jacket; jail; jam; jet;
 jewellery; job; joke; journey; joy; judge; jug; juice; jump; jumper; jungle; junk; kangaroo; kettle; key; kick; kid;
 killing; kilometre; kind; king; kiss; kitchen; kite; kitten; knife; knob; lab; laboratory; ladder; lady; lake; lamb;
 lamp; land; laser; laugh; lawn; lead; leader; leaf; leak; leave; left; leg; legend; lemon; lemonade; length;
 leopard; lesson; letter; level; library; lie; life; light; lightning; line; lion; living; loaf; local; log; look; lounge; love;
 lunch; lunchtime; machine; machinery; magic; mail; man; mango; march; mark; market; mask; master;
 match; maths; matter; may; meal; means; meat; mechanic; medal; medicine; medium; member; mention;
 menu; mercy; mess; message; metal; metre; microphone; midnight; milk; mind; mine; mint; miracle; mirror;
 miss; missile; mode; model; moment; monday; money; monkey; monster; month; morning; mother; motor;
 motorbike; mouse; mouth; move; movement; movie; mr; mrs; mud; mug; mum; museum; mushroom; music;
 musical; mystery; name; nap; neck; necklace; need; neighbour; net; news; newspaper; night; noise; nose;
 november; number; obstacle; ocean; october; opening; opera; opposite; orange; organ; oven; owl; owner;
 pack; packet; pain; paint; painting; pair; palace; palm; pan; pancake; pants; paper; parade; paragraph;
 parcel; parent; park; parrot; part; partner; party; pass; pasta; patch; path; paw; pay; peace; pen; pencil;
 penguin; people; pepper; person; pet; petrol; phone; photo; piano; picture; pie; piece; pig; pile; pillow; pink;
 pipe; pirate; pit; pizza; place; plan; plane; planet; planning; plant; play; player; playground; plot; point; pole;
 police; pond; pony; pool; pop; pork; port; pot; potato; pound; power; practice; prawn; present; presentation;
 president; prince; princess; principal; prize; problem; professor; promise; punch; puppy; purple; push;
 quarter; queen; quiet; rabbit; race; radio; rain; rainbow; rat; razor; read; reading; record; red; rescue;
 research; rest; restaurant; reward; rice; ride; rider; right; ring; river; road; roar; robot; rock; rocket; roll; roof;
 room; rope; round; roundabout; rubber; run; running; sack; salad; salt; sand; sandwich; saturday; sausage;
 saying; scarf; school; science; scooter; score; scratch; screen; sea; seal; search; seat; second; secret;
 section; seed; self; sentence; september; set; shape; share; shark; shed; sheep; sheet; shelf; shelter; ship;
 shoe; shooting; shop; shopkeeper; shopping; shore; shorts; shot; shoulder; show; shower; shuttle; side;
 sight; sign; silver; singing; sip; sir; siren; sister; skate; skeleton; skin; skirt; sky; sleep; slice; smoke; snack;
 snake; snow; soldier; solution; son; song; sound; soup; south; space; speed; spelling; spider; spinach; spirit;
 splash; spoon; spotlight; spray; spread; spring; spy; square; stable; stadium; stage; staircase; stairs; stamp;
 stand; star; start; state; station; stay; step; stick; stomach; stool; stop; store; storey; storm; story; straw;
 strawberry; street; string; student; stuff; style; subject; suit; summer; sun; sunday; surprise; survival; sweets;
 swim; swimming; swing; symbol; table; tail; talent; talk; tank; tap; taxi; tea; teacher; teaching; team; teaspoon;
 teenager; temper; tent; test; text; thanks; thermometer; thing; third; thought; thunderstorm; thursday; tie;
 tiger; timber; time; tin; toast; today; toe; toilet; tomorrow; tongue; tonight; tooth; toothbrush; top; topic; torch;
 touch; towel; tower; town; toy; track; tracksuit; tractor; train; trainer; training; tram; trap; treasure; tree;
 triangle; trick; trip; trophy; trouble; truck; trunk; truth; try; tuesday; tunnel; turkey; turn; turning; tv; type; tyre;

uncle; uniform; unit; university; upgrade; use; wait; walk; walking; wall; valley; war; wardrobe; warrior; wash; wasp; waste; watch; water; waterfall; wave; way; web; website; wedding; wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; victim; video; wife; will; village; win; wind; window; wing; winner; winter; wish; visit; witch; voice; volcano; wolf; woman; wood; wool; word; work; world; worry; worst; wrist; writing; yacht; yard; year; yellow; zebra; zone; zoo;

Year 3 (1412 nouns):

account; accuracy; ache; act; action; activity; actor; ad; addition; address; adult; adventure; advice; aeroplane; afternoon; age; agent; ages; air; airport; alarm; album; alcohol; allowance; alphabet; angel; angle; animal; ankle; announcement; answer; ant; apartment; apple; area; arm; army; arrest; art; artist; assistant; attack; attention; audience; august; aunt; author; autumn; award; baby; back; backing; backpack; bacon; bag; bakery; balcony; ball; ballet; balloon; banana; band; bandage; bang; bank; bar; barbecue; barber; bark; barrier; base; baseball; basement; basket; basketball; bat; bath; bathroom; battery; battle; bay; beach; beam; bean; bear; beat; beauty; bed; bedroom; bee; beef; beer; beginning; behaviour; bell; belt; bench; berry; bet; bicycle; bike; bin; bird; birthday; bit; bite; black; blackboard; blade; blanket; blend; block; blood; blow; blue; board; boat; body; bomb; bone; book; booking; boost; boss; bottle; bottom; bow; bowl; box; boxing; boy; boyfriend; brain; brake; branch; brand; bread; break; breakfast; breath; breed; bribe; brick; bride; bridge; brother; brown; brush; bubble; bucket; bug; builder; building; bulb; bull; bullet; bully; bump; bunch; burger; bus; bush; business; butter; butterfly; button; buzz; cab; cabbage; cabin; cage; cake; calculator; calendar; call; camel; camera; camp; camping; campsite; can; cancer; canteen; cap; capital; captain; capture; car; card; care; carnival; carpet; carrot; cartoon; case; cash; casserole; cast; castle; cat; cause; cave; ceiling; cell; cent; centre; cereal; chain; chair; challenge; champion; championship; chance; change; chapter; character; charge; charm; chat; check; cheer; cheese; chef; chess; chest; chicken; child; chilli; chimney; chin; chip; chocolate; choice; church; cinema; circle; circus; city; class; classic; classroom; click; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; clue; clutch; coach; coal; coat; coconut; code; coffee; coin; cola; cold; collar; collection; college; colour; column; comedy; comic; company; competition; complex; computer; concert; control; cook; cookie; cooking; core; corn; corner; cost; costume; cottage; cotton; cough; count; counter; country; couple; courage; course; court; cousin; cow; cover; crab; crack; craft; crash; cream; creature; creep; crew; cricket; crime; crocodile; cross; crowd; cruise; cry; crystal; cup; cupboard; curve; custom; customer; cut; cutlery; dad; damage; dance; dancer; dancing; danger; darkness; darling; dash; date; daughter; dawn; day; death; december; deck; deer; defeat; defence; defender; delivery; desert; design; desire; desk; dessert; detective; devil; diamond; diary; dice; diet; difference; dinner; dinosaur; directions; dirt; disaster; disc; disco; disease; disguise; dishwasher; disk; distance; dive; diver; diving; division; dock; doctor; dog; doll; dollar; dolphin; domination; donkey; doom; door; dot; dr; draft; drain; drawer; drawing; dream; dress; drink; drive; driver; drop; drum; duck; dump; dust; duty; ear; earth; earthquake; ease; east; edge; egg; electricity; element; elephant; email; empire; end; enemy; energy; engine; enthusiasm; entrance; envelope; equipment; error; escape; evening; evil; excitement; excuse; exercise; experiment; expert; explosion; explosive; expression; extra; eye; face; fact; factory; fake; fall; fame; family; fantasy; farm; farmer; fashion; fat; father; favourite; fear; feeling; female; fence; ferry; field; fifth; fight; fighting; figure; final; fine; finger; fingernail; finish; fire; fish; fishing; fist; fitness; flash; flat; flavour; flesh; flight; floor; flour; flower; flu; fly; fog; food; fool; foot; football; footballer; force; forest; form; fortune; fox; frame; friday; fridge; friend; fright; frog; fruit; fun; funeral; fur; furniture; future; game; gang; gap; garage; garden; gas; gate; gathering; gear; ghost; giant; gift; girl; glance; glass; glasses; glow; glue; go; goal; goalkeeper; god; gold; golf; good; goodness; goods; government; grade; grandfather; grandma; grandmother; grandpa; grandson; grant; grass; green; grey; grin; grip; groom; ground; group; guard; guess; guest; guide; guitar; gum; gun; guts; guy; gym; gymnastics; hail; hair; hairdresser; hall; ham; hammer; hand; handle; happiness; harmony; hat; hate; head; heading; health; heart; heat; heaven; hedge; height; helicopter; hell; helmet; help; hero; hill; history; hit; hobby; hockey; hold; hole; holiday; home; homework; honesty; honey; hood; hope; horn; horror; horse; hospital; host; hotel; hour; house; hug; human; hunt; hunting; hurry; husband; ice; idea; imagination; inch; indicator; information; ink; inside; interior; invasion; invention; investigation; invitation; iron; island; it; item; jacket; jail; jam; january; jar; jaw; jeans; jet; jewellery; job; joke; journal; journey; joy; juice; july; jump; jumper; june; jungle; junk; kangaroo; keeper; kettle; key; keyboard; kick; kid; killer; killing; kind; king; kingdom; kiss; kit; kitchen; kite; kitten; knife; knot; lab; laboratory; labour; lad; ladder; lady; lake; lamb; lamp; land; landing; lane; language; lap; laptop; laser; laugh; launch; law; lawn; layer; lead; leader; leap; learning; leave; left; leg; legend; lemon; lemonade; leopard; lesson; letter; lettuce; level; liar; library; lie; life; lifetime; lift; light; lighting; lightning; line; link; lion; lip; list; literacy; litre; liver; living; lock; log; look; lounge; love; luck; luggage; lunch; lunchtime; machine; magazine; magic; mail; man; manager; mango; mansion; map; march; mark; market; mask; master; mat; match; mate; maths; matter; may; mayor; meal; means; measure; meat; medal; medication; medicine; meeting; member; membership; mention; menu; mess; message; metal; method; microphone; midnight; milk; mind; mine; miner; minute; mirror; miss; missile; mission; mist; mistake; mix; mixture; mobile; mode; model; moment; monday; money; monkey; monster; month; mood; moonlight; morning; mother; motorbike; mountain; mouse; mouth; move; movement; movie; mr; mrs; ms; mud; mug; mum; murder; muscle; museum; music; mystery; nail; name; nap; neck; necklace; need; needle; neighbour;

nest; net; news; newspaper; night; nightmare; noise; north; nose; note; notice; number; nurse; nursery; nut; oak; object; obstacle; ocean; october; offence; office; officer; oil; onion; opening; opera; opponent; opposite; orange; oven; owl; owner; oxygen; pace; pack; packet; page; pain; paint; painting; pair; palace; pan; pancake; pants; paper; parachute; parcel; parent; park; parking; part; partner; party; pass; password; pastry; patch; path; pattern; pause; pay; pea; peace; peach; pedal; pencil; penguin; people; perfume; person; personality; pet; petrol; phone; photo; photographer; piano; picnic; picture; pie; piece; pig; pillow; pilot; pin; pineapple; pink; pirate; pit; pitch; pizza; place; plan; plane; planet; planning; plant; plastic; plate; platform; play; player; playground; pleasure; plug; plus; pocket; poem; point; pole; police; pond; pony; pool; pop; pork; port; position; post; poster; pot; potato; pound; powder; power; practice; prawn; present; president; priest; prince; princess; principal; prison; prisoner; prize; problem; professional; professor; profile; program; promise; proper; property; pub; pudding; punch; puppy; purple; push; pyjamas; pyramid; quarter; queen; quest; question; quiet; quiz; rabbit; race; radio; rail; rain; rainbow; raincoat; rally; rap; rat; rating; ray; razor; reach; read; reader; reading; reason; recipe; rectangle; red; reflection; region; relief; reply; report; rescue; research; rest; restaurant; return; revenge; rice; ride; rider; right; ring; river; road; roar; robbery; robot; rock; rocket; roll; roof; room; rope; rose; round; row; rubber; rubbish; rule; ruler; run; running; runway; rush; saddle; safety; sailing; salad; sale; salmon; salt; sand; sandwich; saturday; sauce; sausage; saying; scar; scarf; school; science; scientist; scooter; scope; score; scrap; scratch; scream; sea; seal; search; season; seat; second; secret; section; security; seed; self; sense; sentence; series; service; session; set; setting; shadow; shape; share; shark; shed; sheep; sheet; shelf; shell; shelter; shield; shift; ship; shirt; shock; shoe; shooting; shop; shopkeeper; shopping; shorts; shot; shoulder; show; shower; shuttle; side; sight; sign; signal; silence; silver; singer; singing; single; sink; sir; siren; sister; site; size; skate; skateboard; skating; skeleton; skiing; skill; skin; skirt; skull; sky; slap; sleep; slice; smell; smile; smoke; smoking; snack; snake; snow; soap; sofa; soil; soldier; solo; son; song; sort; sound; soup; source; south; space; speaker; species; speech; speed; spelling; spending; sphere; spider; spine; spirit; spoon; sport; spot; spotlight; spray; spread; spring; spy; squad; square; squash; stadium; staff; stage; stairs; stand; standard; star; start; state; station; statue; stay; steak; steam; step; stick; stomach; stone; stop; store; storey; storm; story; straw; strawberry; stream; street; stretch; strike; string; stroke; stroll; student; studio; study; stuff; subject; substance; sugar; suit; summer; sun; sunday; sunglasses; sunlight; supermarket; supporter; surface; surfing; surprise; surroundings; survivor; swan; sweat; sweet; swim; swimmer; swimming; swing; switch; sword; system; table; tail; talk; tank; tap; target; taste; taxi; tea; teacher; teaching; team; teaspoon; teenager; telescope; television; tennis; tent; term; test; text; thanks; theatre; theme; thief; thing; third; thought; thunder; thunderstorm; thursday; tick; ticket; tie; tiger; time; tin; tissue; title; toast; today; toe; toilet; tomato; tomb; tomorrow; tongue; tonight; tooth; top; topic; torch; tornado; touch; tour; tournament; towel; tower; town; toy; track; traffic; trail; train; trainer; training; transport; trap; trash; travel; tray; treasure; treat; tree; tribe; trick; trip; troops; trophy; trouble; truck; trumpet; trunk; trust; truth; try; tube; tuesday; tune; tunnel; turn; turning; tv; twin; type; tyre; uncle; underwear; uniform; unit; use; wait; walk; walking; wall; wallet; valley; van; war; wardrobe; warehouse; warning; warrior; wash; watch; water; waterfall; wave; way; weapon; weather; web; website; wedding; wednesday; week; weekend; vegetable; weight; veil; welcome; verse; version; vest; vet; whale; wheat; wheel; white; vice; video; view; wife; will; village; win; wind; window; windscreen; vine; wine; wing; winner; winter; violin; wire; wish; visit; witch; voice; volcano; wolf; woman; wood; word; work; world; worm; worry; worse; worst; vote; wrist; writer; writing; yard; year; yellow; zebra; zoo;

Year 4 (1445 nouns):

accident; accommodation; achievement; acid; act; action; activity; actor; ad; adult; advantage; adventure; advertisement; aeroplane; afternoon; age; agency; agent; ages; air; airport; alarm; alert; ambulance; amount; amusement; analysis; angel; anger; animal; ankle; answer; ant; apartment; apple; april; arch; area; arm; army; art; association; attack; attention; attraction; august; aunt; award; baby; babysitter; back; background; backpack; bacon; badge; bag; balance; balcony; ball; ballet; balloon; ban; banana; band; bandage; bang; bar; bark; barn; base; baseball; basement; basket; basketball; bat; bath; bathroom; battle; bay; beach; bear; beat; beauty; bed; bedroom; beef; beer; beginning; behaviour; bell; belongings; belt; bench; bend; bet; bicycle; bid; bike; bikini; bill; bin; bird; birth; birthday; bit; bite; black; blanket; block; blood; blow; blue; board; boat; body; bomb; bone; bonus; book; bookshelf; boost; boot; boss; bottle; bottom; bow; bowl; box; boxing; boy; boyfriend; bracelet; brain; branch; bread; break; breakfast; breath; breed; breeze; brick; bridge; brother; brown; brush; bubble; bucket; budget; bug; building; bull; bullet; bully; bump; bunch; bus; bush; butter; butterfly; button; cabin; cage; cake; call; camera; camp; camping; can; cancer; cap; capital; captain; capture; car; card; cardboard; cardigan; care; career; carpet; carrot; cartoon; case; cash; cast; castle; cat; cattle; cave; ceiling; celebration; cell; cent; centimetre; centre; century; cereal; ceremony; chain; chair; challenge; champion; championship; chance; change; channel; chaos; chapter; character; charge; charm; chat; check; cheek; cheer; cheese; chef; cherry; chest; chicken; child; chill; chilli; chimney; chin; chip; chocolate; choice; choir; church; circle; circus; city; class; classic; classmate; classroom; click; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; clown; club; clue; coach; coast; coat; code; coffee; cold; coldness; collapse; collar; colour; combination; comedy; comfort; comic; competition; computer; concert; concrete; condition; confidence; connection; contact; container; contest; control; conversation; cook; cookie; cooking; copper;

copy; corner; cost; costume; cottage; cough; country; couple; courage; course; court; cousin; cow; cover; crack; craft; crash; cream; creature; creep; crew; cricket; crime; crisis; cross; crossing; crowd; crush; cry; crystal; cup; cupboard; cure; customs; cut; dad; damage; dance; dancer; dancing; danger; darkness; darling; dash; date; daughter; day; daytime; deal; death; deck; deer; defeat; description; desert; designer; dessert; detective; devastation; devil; diamond; diary; dictionary; difference; dinner; dinosaur; directions; dirt; disaster; discipline; disco; disguise; display; distance; distraction; division; doctor; dog; doll; dollar; doom; door; doorway; drama; dream; dress; drink; drive; driver; drop; drum; duck; duty; ear; earth; earthquake; east; edge; effect; egg; elbow; election; electricity; element; elephant; emergency; encouragement; end; enemy; energy; engine; entertainment; entrance; envelope; environment; equipment; escape; estate; evening; evil; exam; examination; example; excitement; excuse; exercise; experience; experiment; exploration; explosion; explosive; expression; extra; eye; face; fact; factory; fair; fake; fall; fame; family; fan; farm; fascination; fashion; fat; father; fault; favourite; fear; february; feeling; fence; festival; fever; field; fifth; fight; fighting; figure; final; fine; finish; fire; firm; fish; fishing; flash; flavour; flight; floor; flower; flu; fly; focus; fog; food; foot; football; force; forehead; forest; form; fountain; fox; frame; freedom; freezer; friday; fridge; friend; fright; frog; fruit; fuel; fun; funeral; fur; furniture; fury; future; game; gang; garage; garden; gardening; gas; gasp; gate; gear; gender; ghost; giant; girl; girlfriend; glass; glasses; glow; glove; go; goal; goat; gold; golf; good; goods; government; grade; grandfather; grandma; grandmother; grandpa; grandson; grant; grasp; grass; grave; green; grey; grin; ground; group; guard; guess; guide; guitar; gum; gun; guts; guy; gym; gymnastics; hail; hair; haircut; hall; ham; hammer; hand; handbag; handball; handle; happiness; harm; hat; hate; head; heading; headquarters; health; heap; heart; heat; heater; heaven; heel; height; helicopter; hell; helmet; help; hero; hill; hip; history; hit; hold; hole; holiday; home; homework; honey; hook; hope; horn; horror; horse; hospital; host; hostel; hotel; hour; house; hug; human; hunt; hunting; hurry; husband; hut; ice; idea; imagination; importance; increase; independence; information; injury; inside; insight; interview; invasion; invention; invitation; island; it; jacket; jail; jam; jar; jazz; jeans; jet; jewel; jewellery; job; journey; joy; judge; juice; july; jump; jumper; june; jungle; junk; kangaroo; kettle; key; kick; kid; killer; killing; kind; king; kingdom; kiss; kitchen; kite; kitten; knee; knife; lab; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; layer; lead; leader; leaf; league; leak; learning; leave; left; leg; legend; lemon; lemonade; leopard; lesson; letter; lettuce; level; liberty; library; lid; life; lifetime; lift; light; lighting; lightning; line; lion; liquid; list; literacy; litter; living; loaf; local; lock; log; look; lottery; lounge; love; luck; luggage; lump; lunch; lunchtime; lyrics; machine; magic; mail; maker; male; mall; man; manager; mango; mansion; manual; map; march; margin; mark; market; mask; master; mat; match; mate; material; maths; matter; may; meal; means; meat; mechanic; medal; medicine; medium; meeting; mention; mess; message; metal; metre; midnight; milk; mind; mine; miner; minute; mirror; misery; miss; mission; mist; mistake; mix; mixture; model; moment; monday; money; monkey; monopoly; monster; month; mood; morning; mosquito; mother; motor; motorbike; mountain; mouse; mouth; move; movement; movie; mr; mrs; ms; mud; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; needle; neighbour; neighbourhood; nephew; nerve; nest; net; news; newspaper; nickname; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; occasion; ocean; october; office; officer; official; oil; onion; opening; opponent; opposite; orange; order; orphan; oven; owner; pack; pain; paint; pair; palace; palm; panel; pants; paper; parachute; parade; paradise; parcel; parent; park; parrot; part; party; pass; passage; passenger; passport; pasta; patch; path; patience; pattern; pause; pay; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; pepper; performance; perfume; person; personality; pet; petrol; phone; photo; piano; picnic; picture; pie; piece; pig; pile; pill; pillow; pilot; pin; pink; pipe; pirate; pit; pitch; pizza; place; plan; plane; planet; planning; plant; plastic; plate; platform; play; player; playground; pleasure; plumber; pocket; point; poison; pole; police; policeman; pony; pool; pop; post; poster; pound; powder; power; practice; predator; present; president; pressure; price; prince; princess; principal; print; prison; prize; problem; production; professional; professor; profile; progress; project; promise; property; protection; pulse; pump; punch; punishment; puppy; purple; purpose; purse; push; puzzle; pyjamas; quarter; queen; quest; question; quiet; quiz; rabbit; race; radio; raid; railway; rain; rainbow; raincoat; rainforest; rally; rat; ray; reach; read; reading; realm; reason; recipe; rectangle; red; referee; register; release; remains; rent; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; ride; rider; right; ring; risk; river; road; roar; robbery; robot; rock; rocket; roll; roof; room; root; rope; rose; round; routine; row; rubber; rugby; rule; ruler; rumour; run; running; rush; sack; saddle; sadness; safety; sail; salad; sale; sample; sand; sandwich; saturday; sauce; saucepan; saucer; sausage; saving; saying; scar; scarf; scene; scent; scholarship; school; science; scientist; scissors; scooter; score; scream; screen; sea; search; season; seat; second; secret; section; security; seed; self; sense; september; series; servant; service; set; setting; shade; shadow; shame; shampoo; shape; share; shark; shed; sheep; sheet; shell; shelter; shift; ship; shirt; shock; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; shuttle; sickness; side; sight; sign; signal; silence; silver; simulation; singer; singing; single; sink; sir; siren; sister; site; situation; size; skate; skateboard; skateboarding; skeleton; sketch; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smell; smile; smoke; snack; snake; snow; society; soldier; son; song; sort; soul; sound; soup; south; souvenir; soya; space; spade; speaker; species; speed; spelling; spending; sphere; spider; spine; splash; spoon; sport; spot; spray; spread; spy; squad; square; stable; stadium; staff; stage; staircase; stairs;

stand; star; stardom; start; starvation; state; station; statue; status; stay; steel; step; stick; stitch; stomach; stone; stool; stop; store; storey; storm; story; stranger; strawberry; stream; street; strength; stretch; strike; string; stripe; stroke; stroll; study; stuff; style; subject; substitute; success; sugar; suit; suitcase; sum; summer; summit; sun; sunday; sunlight; sunset; sunshine; supermarket; supply; surface; surfing; surgery; surprise; surroundings; sweat; sweet; sweets; swim; swimming; swing; switch; sword; system; table; tail; tale; talk; talks; tank; tap; target; taste; taxi; tea; teacher; teaching; team; tear; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; term; terror; test; thanks; theft; theme; thief; thing; third; thought; thrill; throat; throne; thunder; thursday; tick; ticket; tide; tie; tiger; tights; timber; time; tin; tip; toast; today; toe; toilet; tomato; tomorrow; ton; tone; tongue; tonight; tooth; top; topic; torch; tornado; torture; total; touch; tour; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; trainer; training; transport; trap; travel; treasure; tree; triangle; trick; trip; trolley; trophy; trouble; truck; trust; try; tube; tuesday; tune; tunnel; turn; turning; tv; twin; type; tyre; umbrella; uncle; underwear; university; use; waist; wait; waitress; walk; walker; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warning; warrior; wash; waste; watch; water; waterfall; wave; way; weapon; weather; web; webcam; wedding; wednesday; weed; week; weekend; vegetable; vegetarian; weight; welcome; velvet; version; west; vet; whale; wheat; wheel; whistle; white; video; widow; view; wife; will; village; win; wind; window; vine; wing; winner; winter; violence; wish; visit; witch; voice; volcano; wolf; volleyball; woman; wood; wool; word; work; worker; world; worm; worry; worse; worst; vote; wreck; wreckage; writer; writing; yard; year; yell; yellow; zip; zone; zoo;

Appendix AC

As discussed in Subchapter 11.2, we identified 3710 unique nouns in vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile covering cumulative vocabularies of six language ability levels ranging from A1 to C2 (as of June-July 2013). In hyperlink network of Wikipedia (as of June-July 2013) between these 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 we identified 25153 unique interconnecting hyperlinks containing 2878 unique nouns. Following listing contains all 25153 unique hyperlinks, here notation A>B denotes a hyperlink leading from concept A to concept B (corresponding to a hyperlink leading from Wikipedia article A to Wikipedia article B).

All 25153 unique hyperlinks between 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns:

ability>intelligence; ability>skill; abortion>contraceptive; abortion>rape; abortion>terrorism; abuse>accident; abuse>aggression; abuse>anger; abuse>anxiety; abuse>behaviour; abuse>childhood; abuse>consent; abuse>crime; abuse>criticism; abuse>denial; abuse>disability; abuse>discrimination; abuse>dislike; abuse>embarrassment; abuse>exaggeration; abuse>fear; abuse>gang; abuse>gender; abuse>harassment; abuse>harm; abuse>hatred; abuse>health; abuse>human; abuse>humility; abuse>individual; abuse>injustice; abuse>insult; abuse>jealousy; abuse>language; abuse>liberty; abuse>memory; abuse>metaphor; abuse>morale; abuse>neglect; abuse>negligence; abuse>pain; abuse>perception; abuse>persuasion; abuse>prejudice; abuse>pride; abuse>psychology; abuse>racism; abuse>rape; abuse>reputation; abuse>resentment; abuse>respect; abuse>self-esteem; abuse>shame; abuse>skill; abuse>slavery; abuse>solitude; abuse>suffering; abuse>threat; abuse>torture; abuse>vandalism; abuse>violence; accent>drawing; acceptance>anxiety; acceptance>human; acceptance>motivation; acceptance>peer pressure; acceptance>psychology; acceptance>reality; acceptance>self-esteem; acceptance>suffering; accident>injury; accident>leisure; accident>necessity; accident>safety; accident>secret; account>report; accountant>business; accountant>profession; accountant>university; ache>pain; acid>alcohol; acid>aspirin; acid>bacteria; acid>carbon dioxide; acid>cola; acid>dna; acid>fat; acid>gas; acid>liquid; acid>mammal; acid>protein; acid>solution; acid>stomach; acid>vinegar; acre>area; acre>day; acre>metre; acre>yard; act>document; act>pact; act>peace; act>war; actor>celebrity; actor>comic; actor>drama; actor>film; actor>ghost; actor>hysteric; actor>opera; actor>person; actor>song; actor>system; actor>television; actor>theatre; actor>tragedy; adaptation>behaviour; adaptation>climate; adaptation>crab; adaptation>deer; adaptation>evolution; adaptation>extinction; adaptation>genetics; adaptation>habitat; adaptation>immune system; adaptation>infection; adaptation>learning; adaptation>rat; addict>addiction; addiction>alcohol; addiction>anxiety; addiction>dna; addiction>gambling; addiction>genetics; addiction>motivation; addiction>reasoning; addiction>withdrawal; addition>angle; addition>apple; addition>circle; addition>computer; addition>force; addition>infant; addition>noun; addition>paper; addition>pie; addition>pressure; addition>toddler; addition>verb; adjective>adverb; adjective>clause; adjective>determiner; adjective>grammar; adjective>infinitive; adjective>language; adjective>noun; adjective>preposition; adjective>quantity; adjective>verb; administration>management; admiration>awe; admiration>envy; adoption>abortion; adoption>court; adoption>inheritance; adoption>stereotype; adult>biology; adult>child; adult>contract; adult>employment; adult>gambling; adult>law; adult>lottery; adult>marriage; adult>person; adult>president; adult>prostitute; adult>reproduction; adult>sex; adventure>excitement; adventure>extreme sports; adventure>fear; adventure>learning; adventure>recreation; adventure>risk; adventure>tourism; adverb>adjective; adverb>clause; adverb>comparative; adverb>noun; adverb>superlative; adverb>verb; advert>advertising; advertisement>advertising; advertising>aircraft; advertising>attention; advertising>blog; advertising>brand; advertising>brochure; advertising>camera; advertising>communication; advertising>consumer; advertising>creativity; advertising>design; advertising>female; advertising>gender; advertising>household; advertising>information; advertising>logo; advertising>magazine; advertising>marketing; advertising>message; advertising>newspaper; advertising>persuasion; advertising>poster; advertising>problem; advertising>propaganda; advertising>radio; advertising>reality; advertising>rocket; advertising>tram; advertising>website; advice>advocate; advocate>court; advocate>judge; advocate>law; advocate>lawyer; advocate>profession; advocate>prosecutor; advocate>solicitor; affair>deception; affair>integrity; affair>lie; affair>marriage; affair>sex; affection>communication; affection>emotion; affection>friendship; affection>love; affection>philosophy; affection>psychology; afternoon>evening; afternoon>midday; afternoon>midnight; afternoon>noon; afternoon>summer; age>gold; agent>robot; agent>title; aggression>adaptation; aggression>anger; aggression>animal; aggression>capitalism; aggression>evolution; aggression>fear; aggression>hostility; aggression>injustice; aggression>learning; aggression>peer pressure; aggression>poverty; aggression>property; aggression>resource; aggression>revenge; aggression>survival; aggression>trade; aggression>violence; agreement>consensus; agreement>contract; agreement>disagreement; agreement>treaty; agriculture>ant; agriculture>bean; agriculture>camel; agriculture>carbon dioxide; agriculture>cereal; agriculture>civilization; agriculture>climate; agriculture>climate change; agriculture>cotton; agriculture>donkey; agriculture>drug; agriculture>famine; agriculture>food; agriculture>fruit; agriculture>fuel; agriculture>genetics; agriculture>global warming; agriculture>grain; agriculture>grape; agriculture>harvest; agriculture>insect; agriculture>meat; agriculture>pea; agriculture>perfume; agriculture>plant; agriculture>potato; agriculture>productivity; agriculture>rice; agriculture>riot; agriculture>root; agriculture>satellite; agriculture>silk; agriculture>spice; agriculture>sustainability; agriculture>tobacco; agriculture>tractor; agriculture>vegetable; agriculture>wheat; agriculture>wine; agriculture>wool; aid>capitalism; aid>commerce; aid>country; aid>diplomacy; aid>donation; aid>government; aid>infrastructure; aid>interaction; aid>loan; aid>penguin; aid>scholar; aid>starvation; aid>transport; aid>vaccine; aid>war; air conditioning>air; air conditioning>biology; air conditioning>carbon; air conditioning>carbon dioxide; air conditioning>central heating; air conditioning>chemistry; air conditioning>climate; air conditioning>construction; air conditioning>cooking; air conditioning>frost; air conditioning>gas; air conditioning>hospital; air conditioning>ice; air conditioning>infection; air conditioning>invention; air conditioning>inventor; air conditioning>laboratory; air conditioning>liquid; air conditioning>mining; air conditioning>oxygen; air conditioning>ozone; air conditioning>pressure; air conditioning>sun; air conditioning>system; air conditioning>temperature; air force>balloon; air force>bomber; air force>missile; aircraft>air; aircraft>airport; aircraft>atmosphere; aircraft>balloon; aircraft>bomber; aircraft>cargo; aircraft>flight; aircraft>helicopter; aircraft>human; aircraft>kite; aircraft>landing; aircraft>missile; aircraft>rocket; aircraft>wind; aircraft>wing; airline>aircraft; airline>airport; airline>cargo; airline>corporation; airline>fuel; airline>mail; airline>partnership; airline>passenger; airline>takeover; airlines>travel; airport>accident; airport>agriculture; airport>airline; airport>airline; airport>bird; airport>brake; airport>concrete; airport>corporation; airport>erosion; airport>film; airport>flood; airport>fog; airport>government; airport>grass; airport>helicopter; airport>hotel; airport>ice; airport>immigration; airport>landing; airport>mountain; airport>navy; airport>politician; airport>public transport; airport>radio; airport>rain; airport>road; airport>runway; airport>snow; airport>terrorism; airport>tree; airport>weather; alarm clock>clock; alarm clock>nap; alarm clock>radio; alarm clock>sleep; alarm clock>time; album>lyrics; alcohol>acid; alcohol>alcoholic; alcohol>carbon; alcohol>carbon dioxide; alcohol>chemistry; alcohol>cholesterol; alcohol>metal; alcohol>oxygen; alcohol>perfume; alcohol>salt; alcohol>soap; allegation>complaint; allegation>fact; alliance>airline; alliance>contract; alliance>friendship; alliance>pact; alliance>treaty; allowance>supermarket; alphabet>consonant; alphabet>language; alphabet>spelling; alphabet>syllable; alphabet>turkey; alphabet>vowel; aluminium>adaptation; aluminium>bacteria; aluminium>bicycle; aluminium>carbon; aluminium>coin; aluminium>concrete; aluminium>copper; aluminium>density; aluminium>deodorant; aluminium>digestion; aluminium>door; aluminium>earth; aluminium>glass; aluminium>gold; aluminium>iron; aluminium>leather; aluminium>metal; aluminium>mirror; aluminium>ocean; aluminium>oxygen; aluminium>paint; aluminium>recycling; aluminium>rubber; aluminium>silver; aluminium>steel; aluminium>tin; aluminium>transport; aluminium>truck; aluminium>water; aluminium>wheat; aluminium>window; aluminium>year; amateur>astronomy; amateur>baseball; amateur>basketball; amateur>boxing; amateur>hobby; amateur>professional; ambassador>diplomacy; ambassador>diplomat; ambassador>embassy; ambiguity>bank; ambiguity>creativity; ambiguity>dimension; ambiguity>gain; ambiguity>jargon; ambiguity>leadership; ambiguity>literature; ambiguity>logic; ambiguity>metre; ambiguity>music; ambiguity>paradox; ambiguity>pharmacist; ambiguity>pharmacy; ambiguity>philosopher; ambiguity>physics; ambiguity>prefix; ambiguity>rhythm; ambiguity>sadness; ambiguity>science; ambiguity>suffix; ambiguity>uncertainty; ambiguity>vocabulary; ambulance>air conditioning; ambulance>bicycle; ambulance>disaster; ambulance>electronics; ambulance>firefighter; ambulance>fuel; ambulance>helicopter; ambulance>illness; ambulance>injury; ambulance>mobile phone; ambulance>tank; ambulance>traffic light; ambulance>weapon; ambulance>vehicle; ambulance>wheelchair; amendment>constitution; amendment>contract; amendment>law; amendment>motion; amendment>parliament; amendment>referendum; amendment>verb; amount>quantity; amusement>enjoyment; amusement>entertainment; amusement>experience; amusement>happiness; amusement>humour; amusement>laughter; amusement>pleasure; analogy>argument; analogy>atom; analogy>authority; analogy>common sense; analogy>communication; analogy>creativity; analogy>culture; analogy>emotion; analogy>evolution; analogy>explanation; analogy>fight; analogy>god; analogy>idiom; analogy>information; analogy>insect; analogy>language; analogy>law; analogy>logic; analogy>memory; analogy>message; analogy>metaphor; analogy>perception; analogy>philosophy; analogy>politics; analogy>precedent; analogy>probability; analogy>proverb; analogy>psychology; analogy>role; analogy>science; analogy>software; analogy>sun; analogy>truth; analogy>verb; analogy>writing; analysis>chemistry; analysis>complexity; analysis>electronics; analysis>engineering; analysis>geology; analysis>language; analysis>literature; analysis>logic; analysis>mixture; analysis>police; analysis>statistics; ancestor>bacteria; ancestor>dna; ancestor>evolution; ancestor>genetics; ancestor>grandparent; ancestor>parent; anchor>cable; anchor>chain; anchor>rope; anchor>storm; angel>atmosphere; angel>birth; angel>earth; angel>evolution; angel>breath; angel>global warming; angel>god; angel>heaven; angel>hell; angel>icon; angel>matter; angel>nature; angel>planet; angel>religion; angel>spirit; angel>star; angel>sun; angel>time; anger>aggression; anger>angel; anger>appetite; anger>criticism; anger>devil; anger>discrimination; anger>emotion; anger>evaluation; anger>god; anger>gossip; anger>hatred; anger>hostility; anger>humility; anger>infection; anger>intelligence; anger>negotiation; anger>pain; anger>perception; anger>punishment; anger>rage; anger>rape; anger>resentment; anger>revenge; anger>selfishness; anger>sense; anger>society; anger>statistics; anger>threat; anger>violence; anger>virtue; angle>ankle; angle>astronomy; angle>curve; angle>earth; angle>geography; angle>kilometre; angle>star; angle>surface; angle>triangle; animal>bacteria; animal>body; animal>bone; animal>breath; animal>carbon dioxide; animal>coral; animal>digestion; animal>evolution; animal>extinction; animal>fish; animal>gene; animal>lung; animal>mammal; animal>muscle; animal>oxygen; animal>protein; animal>reptile; animal>sunlight; animal>trait; animation>blackboard; animation>camera; animation>computer; animation>glass; animation>illusion; animation>light; animation>software; animation>the internet; ankle>foot; ankle>joint; ankle>pain; anniversary>birthday; anniversary>constitution; anniversary>day; anniversary>millennium; anniversary>saint; annoyance>anger; annoyance>distraction; annoyance>emotion; annoyance>frustration; annoyance>thought; answer>complaint; answer>imprisonment; answer>information; answer>lawyer; answer>punishment; answer>question; answer>reply; ant>adaptation; ant>animal; ant>bee; ant>carbon dioxide; ant>civilization; ant>earth; ant>ecology; ant>evolution; ant>human; ant>insect; ant>mammal; ant>muscle; ant>predator; ant>region; ant>soil; ant>trail; ant>wasp; antique>bronze; antique>pine; anxiety>authority; anxiety>digestion; anxiety>fear; anxiety>headache; anxiety>immune system; anxiety>reality; anxiety>self-esteem; anxiety>symptom; anxiety>terror; anxiety>tradition; apartment>bathroom; apartment>bedroom; apartment>brick; apartment>building; apartment>furniture; apartment>house; apartment>laundry; apartment>loft; apartment>parking; apartment>pet; apartment>telephone; apartment>theft; apartment>waste; apostrophe>advertising; apostrophe>definite article; apostrophe>dice; apostrophe>hyphen; apostrophe>noun; apostrophe>penny; apostrophe>plural; apostrophe>punctuation; apostrophe>suffix; apostrophe>vandalism; apostrophe>vowel; appeal>law; appetite>brain; appetite>food; appetite>obesity;

applause>audience; applause>comedian; applause>concert; applause>golf; applause>jazz; applause>news; applause>opera; applause>prime minister; applause>television;
apple>ancestor; apple>carbon dioxide; apple>evil; apple>fruit; apple>leaf; apple>obesity; apple>oxygen; apple>plant; apple>proverb; apple>seed; apple>tree; apple>turkey;
apple>vinegar; application>question; april>autumn; april>month; april>october; arch>concrete; arch>erosion; arch>structure; archaeologist>archaeology; archaeology>agriculture;
archaeology>analysis; archaeology>architecture; archaeology>astronomy; archaeology>bureaucracy; archaeology>camera; archaeology>cereal; archaeology>chemistry;
archaeology>computer; archaeology>construction; archaeology>elite; archaeology>evolution; archaeology>geography; archaeology>geology; archaeology>history;
archaeology>human; archaeology>hypothesis; archaeology>iron; archaeology>kite; archaeology>library; archaeology>literacy; archaeology>map; archaeology>physics;
archaeology>plant; archaeology>religion; archaeology>science; archaeology>statistics; archaeology>tool; architect>architecture; architect>artist; architect>construction;
architect>engineer; architect>engineering; architect>profession; architecture>architect; architecture>artist; architecture>building; architecture>construction; architecture>craft;
architecture>design; architecture>engineer; architecture>engineering; architecture>lighting; architecture>planning; architecture>structure; architecture>sustainability;
architecture>system; area>acre; area>addition; area>analogy; area>analysis; area>circle; area>definition; area>formula; area>inch; area>length; area>metre; area>paint;
area>quantity; area>rectangle; area>shape; area>sphere; area>surface; area>triangle; area>volume; argument>analogy; argument>evidence; argument>inquiry; argument>logic;
argument>philosophy; argument>proposition; argument>reason; argument>truth; argument>validity; arm>elbow; arm>hand; arm>shoulder; arm>wrist; army>air force; army>nation;
army>soldier; army>troops; army>war; army>veteran; arrangement>cello; arrangement>guitar; arrangement>orchestra; arrangement>violin; arrest>crime; arrest>detective;
arrest>liberty; arrest>police; arrest>police station; arrest>riot; arrest>unemployment; arrow>aluminium; arrow>blood; arrow>bone; arrow>copper; arrow>feather; arrow>gram;
arrow>human; arrow>inch; arrow>quarrel; arrow>wood; art>architecture; art>beauty; art>cancer; art>coin; art>cooking; art>craft; art>creativity; art>dance; art>design;
art>dvd; art>emotion; art>farming; art>film; art>globalization; art>human; art>language; art>literature; art>medicine; art>music; art>nature; art>painting; art>peasant; art>philosophy;
art>photography; art>pollution; art>propaganda; art>sculpture; art>shape; art>theatre; artificial intelligence>computer; artificial intelligence>consciousness; artificial
intelligence>cooperation; artificial intelligence>creativity; artificial intelligence>empathy; artificial intelligence>firm; artificial intelligence>logic; artificial intelligence>mind; artificial
intelligence>paradigm; artificial intelligence>perception; artificial intelligence>probability; artificial intelligence>psychology; artificial intelligence>uncertainty; artist>actor;
artist>animation; artist>architect; artist>art; artist>astronomy; artist>ballet; artist>beauty; artist>chemistry; artist>comedy; artist>craft; artist>creativity; artist>criticism; artist>culture;
artist>dance; artist>dancing; artist>design; artist>doll; artist>drawing; artist>entertainer; artist>entertainment; artist>fiction; artist>genius; artist>history; artist>innovation; artist>lyrics;
artist>medicine; artist>music; artist>musician; artist>painting; artist>photography; artist>poetry; artist>pottery; artist>project; artist>sculpture; artist>singing; artist>skill; artist>speech;
artist>technician; artist>technology; artist>tragedy; artist>writing; aspiration>hope; aspirin>acid; aspirin>bark; aspirin>cancer; aspirin>decade; aspirin>experiment; aspirin>fever;
aspirin>gender; aspirin>heart attack; aspirin>kidney; aspirin>liver; aspirin>medication; aspirin>protein; aspirin>stomach; aspirin>stroke; aspirin>vinegar; assault>arrest;
assault>boxing; assault>police; assault>pride; assault>rape; assault>terrorism; assembly>manufacturing; assembly>meeting; asset>building; asset>cash; asset>currency;
asset>economics; asset>furniture; asset>insurance; asset>investment; asset>machinery; asset>ownership; asset>stock; asset>tool; asset>wealth; asset>website; assistance>aid;
assumption>proposition; assurance>insurance; astronomy>archaeology; astronomy>atmosphere; astronomy>atom; astronomy>calendar; astronomy>chemical;
astronomy>chemistry; astronomy>earth; astronomy>erosion; astronomy>light; astronomy>matter; astronomy>photography; astronomy>physics; astronomy>planet;
astronomy>radio; astronomy>star; astronomy>sun; astronomy>telescope; astronomy>temperature; astronomy>tornado; astronomy>trace; astronomy>wave; athletics>sport;
atmosphere>carbon dioxide; atmosphere>climate; atmosphere>dust; atmosphere>earth; atmosphere>evolution; atmosphere>force; atmosphere>gas; atmosphere>oxygen;
atmosphere>planet; atmosphere>radiation; atmosphere>sky; atmosphere>space; atmosphere>sunlight; atmosphere>wind; atom>carbon; atom>carbon dioxide; atom>chemist;
atom>chemistry; atom>crystal; atom>diamond; atom>distance; atom>earth; atom>experiment; atom>force; atom>gas; atom>gold; atom>iron; atom>laser; atom>lead; atom>light;
atom>liquid; atom>matter; atom>metal; atom>minimum; atom>momentum; atom>oxygen; atom>ozone; atom>particle; atom>pressure; atom>salt; atom>spectrum; atom>star;
atom>temperature; atom>tin; atom>water; attachment>virus; attempt>arrest; attempt>crime; attempt>impossibility; attempt>judge; attempt>jury; attempt>police;
attention>distraction; attention>education; attention>philosophy; attention>psychology; attention>sense; attribute>board game; attribute>database; auction>business; auction>cattle;
auction>commodity; auction>corporation; auction>debt; auction>fee; auction>marriage; auction>timber; auction>trade; auction>wool; audience>blog; audience>criticism;
audience>literature; audience>music; audience>performance; audience>person; audience>review; audience>scholar; audience>software; audience>theatre; audience>video game;
audition>actor; audition>comedy; audition>dancer; audition>jazz; audition>musician; audition>opera; audition>orchestra; audition>singer; audition>song; august>february;
august>harvest; august>january; august>march; august>month; august>tribe; august>year; aunt>nephew; aunt>niece; aunt>sister-in-law; aunt>uncle; aunt>existence;
author>manufacturing; author>novel; author>person; author>writer; authority>court; authority>crowd; authority>dominance; authority>government; authority>persuasion;
authority>prayer; authority>revolution; autumn>apple; autumn>baseball; autumn>cherry; autumn>harvest; autumn>night; autumn>oak; autumn>season; autumn>summer;
autumn>winter; availability>system; award>badge; award>championship; award>medal; award>prize; award>trophy; awareness>animal; awareness>attention; awareness>brain;
awareness>concept; awareness>consciousness; awareness>experience; awareness>idea; awareness>mind; awareness>pattern; awareness>perception; awareness>self-
awareness; awareness>understanding; awe>anger; awe>curiosity; awe>dinosaur; awe>embarrassment; awe>emotion; awe>enjoyment; awe>fear; awe>happiness; awe>love;
awe>pride; awe>sadness; baby>infant; background>heritage; backpack>camera; backpack>dialect; backpack>hand; backpack>handbag; backpack>hip; backpack>laptop;
backpack>luggage; backpack>plastic; backpack>shoulder; backpack>skateboard; backpack>student; backpack>suitcase; backpacker>backpack; backpacker>hostel;
backpacking>backpacker; backup>cd; backup>data; backup>dvd; backup>raid; bacon>beef; bacon>chicken; bacon>fat; bacon>goat; bacon>ham; bacon>pizza; bacon>potato;
bacon>salt; bacon>sausage; bacon>skin; bacon>teaspoon; bacteria>agriculture; bacteria>antibiotic; bacteria>blood; bacteria>carbon; bacteria>carbon dioxide;
bacteria>carbon monoxide; bacteria>cheese; bacteria>disease; bacteria>dna; bacteria>earth; bacteria>evolution; bacteria>gene; bacteria>genetics; bacteria>habitat;
bacteria>immune system; bacteria>infection; bacteria>medicine; bacteria>nose; bacteria>oxygen; bacteria>plant; bacteria>pollution; bacteria>protein; bacteria>root; bacteria>skin;
bacteria>sphere; bacteria>wildlife; bacteria>wine; bacteria>vinegar; bacteria>virus; bacteria>vitamin; bacteria>yogurt; badge>detective; badge>leather; badge>metal; badge>plastic;
badge>police; badge>uniform; badminton>competition; badminton>leather; badminton>rubber; badminton>table tennis; badminton>tennis; bag>backpack; bag>basket; bag>berry;
bag>cloth; bag>clothing; bag>cookie; bag>fee; bag>hand; bag>handbag; bag>leather; bag>money; bag>paper; bag>plastic; bag>pocket; bag>purse; bag>shopping; bag>suitcase;
bag>tea; bag>tool; bag>travel; baggage>aeroplane; baggage>clothing; baggage>fashion; baggage>passenger; baggage>souvenir; baggage>suitcase; baggage>tourist;
baggage>transport; baggage>travel; baggage>wealth; baggage>vehicle; baker>bakery; baker>bread; baker>cake; baker>employment; baker>fast food; baker>flour; baker>landlord;
baker>loaf; baker>oven; baker>recipe; baker>supermarket; bakery>baker; bakery>bread; bakery>caf  ; bakery>cake; bakery>coffee; bakery>establishment; bakery>flour;
bakery>oven; bakery>retail; bakery>tea; balcony>column; ball>cricket; ball>engineering; ball>football; ball>kitten; ball>puppy; ball>rubber; ball>sphere; ballet>music;
ballet>orchestra; ballet>singing; balloon>gas; balloon>oxygen; balloon>pump; balloon>solution; balloon>stomach; banana>agriculture; banana>archaeology;
banana>bark; banana>carpet; banana>coconut; banana>coffee; banana>cooking; banana>farmer; banana>fruit; banana>ghost; banana>income; banana>mango;
banana>pancake; banana>potato; banana>silk; banana>spirit; banana>sunlight; banana>supermarket; banana>taste; banana>tree; banana>umbrella;
banana>water; banana>vegetable; banana>virus; band>strap; bang>exclamation mark; bank account>credit card; bank>check; bank>cheque; bank>credit card; bank>debit card;
bank>debt; bank>economy; bank>finance; bank>interest; bank>loan; bank>money; bank>overdraft; banker>bank; banking>bank; barbecue>beef; barbecue>casserole;
barbecue>chicken; barbecue>goat; barbecue>pig; barbecue>pork; barbecue>sausage; barbecue>vinegar; barber>beard; barber>comb; barber>dentist; barber>hairstresser;
barber>mirror; barber>razor; barber>surgery; barber>vocation; bargain>contract; bark>aspirin; bark>backpack; bark>disease; bark>famine; bark>mango; bark>pine; bark>potato;
bark>rope; bark>spice; bark>tree; bark>vine; bark>wood; barn>cattle; barn>door; barn>farm; barn>harvest; barn>horse; barn>loft; barn>problem; barn>saddle;
barn>shed; barn>stable; barn>stall; barn>straw; barn>trousers; baseball>basketball; baseball>cricket; baseball>ice hockey; baseball>statistics; basement>central heating;
basement>coal; basement>door; basement>house; basement>industrialization; basement>leak; basement>renovation; basement>slope; basement>spade; basement>storey;
basement>tornado; basement>wine; basket>art; basket>laundry; basket>material; basketball>disability; basketball>peach; basketball>playground; basketball>wheelchair;
bat>animal; bat>bird; bat>blood; bat>death; bat>disease; bat>ear; bat>evolution; bat>eye; bat>fish; bat>flight; bat>flower; bat>fog; bat>food; bat>fruit; bat>genetics;
bat>ghost; bat>hero; bat>hunting; bat>insect; bat>mammal; bat>mosquito; bat>novel; bat>owl; bat>rabbit; bat>skeleton; bat>skin; bat>soup; bat>toe; bat>tongue; bat>vein;
bat>wife; bat>wing; bat>wolf; bathroom>carpet; bathroom>comb; bathroom>heater; bathroom>mat; bathroom>mirror; bathroom>shower; bathroom>sink; bathroom>soap;
bathroom>toilet; bathroom>towel; battle>aircraft; battle>army; battle>castle; battle>combatt; battle>earth; battle>geography; battle>helicopter; battle>information; battle>politics;
battle>radio; battle>sea; battle>space; battle>strategy; battle>tank; battle>transport; battle>war; battle>weapon; bay>anchor; bay>coast; bay>fish; bay>fishing; bay>lake; bay>pond;
bay>port; bay>sea; bay>trade; beach>coast; beach>erosion; beach>sand; beach>shore; beach>waste; beach>wave; beach>bone; beach>evolution; beach>nostril; beach>owl;
bear>reptile; bear>shield; bear>skull; bear>tooth; bear>bacteria; bear>cabbage; bear>cholesterol; bear>iron; bear>oil; bear>pea; bear>protein; bear>seed; bear>vinegar;
bear>animal; bear>ant; bear>bicycle; bear>continent; bear>dna; bear>dog; bear>extinction; bear>fishing; bear>habitat; bear>hunting; bear>insect; bear>naked; bear>mammal;
bear>nickname; bear>polar bear; bear>species; bear>stock market; bear>tiger; bear>tribe; bear>wolf; beard>barber; beard>boxing; beard>cheek; beard>chin; beard>evolution;
beard>goat; beard>government; beard>hair; beard>honour; beard>moustache; beard>neck; beard>philosopher; beard>politics; beard>razor; beard>religion; beard>scissors;
beauty>charisma; beauty>elegance; beauty>harmony; beauty>idea; beauty>integrity; beauty>intelligence; beauty>nature; beauty>perception; beauty>pleasure; beauty>politeness;
beauty>ratio; bed>baby; bed>blanket; bed>bronze; bed>clothing; bed>curtain; bed>door; bed>duvet; bed>fur; bed>furniture; bed>gold; bed>hair; bed>hospital; bed>infant;
bed>iron; bed>leaf; bed>leather; bed>linen; bed>marriage; bed>metal; bed>parliament; bed>pillow; bed>silk; bed>silver; bed>skin; bed>sleep; bed>straw; bed>throne; bed>velvet;
bed>wood; bed>wool; bedroom>apartment; bedroom>bathroom; bedroom>bookcase; bedroom>carpet; bedroom>chest of drawers; bedroom>room; bedroom>wardrobe;
bee>advertising; bee>ant; bee>banana; bee>butterfly; bee>coconut; bee>disease; bee>evolution; bee>flower; bee>gardener; bee>honey; bee>insect; bee>mosquito;
bee>plant; bee>predator; bee>protein; bee>rice; bee>society; bee>wasp; bee>wood; beef>bacteria; beef>barbecue; beef>brain; beef>cattle; beef>cooking; beef>curry;
beef>economics; beef>grain; beef>heart; beef>iron; beef>kidney; beef>leather; beef>liver; beef>meat; beef>milk; beef>muscle; beef>oven; beef>porc; beef>reproduction;
beef>sauce; beef>sausage; beef>steak; beef>supermarket; beef>vinegar; beer>antibiotic; beer>bread; beer>cancer; beer>carbon dioxide; beer>cholesterol; beer>fat;
beer>manufacturing; beer>protein; beer>soft drink; beer>stroke; beer>sugar; beer>tea; beer>thermometer; belief>advertising; belief>faith; belief>idea; belief>knowledge;
belief>opinion; belief>proposition; belief>religion; belief>suggestion; belief>truth; benefit>consideration; benefit>economics; benefit>insurance; benefit>law; benefit>system;
benefit>well-being; berry>banana; berry>cherry; berry>fruit; berry>grape; berry>lemon; berry>olive; berry>peach; berry>poison; berry>potato; berry>seed; berry>skin;
berry>strawberry; berry>tomato; bestseller>advertising; bestseller>book; bestseller>chart; bestseller>fiction; bestseller>film; bestseller>marketing; bestseller>novel;
bestseller>professor; bestseller>publicity; bestseller>publisher; bestseller>retailer; bet>gambling; bias>audience; bias>employment; bias>government; bias>journalist;
bias>ownership; bias>preference; bias>prejudice; bias>racism; bicycle>carbon dioxide; bicycle>cycling; bicycle>hand; bicycle>mail; bicycle>recreation; bicycle>sport;
bicycle>transport; bike>bicycle; bikini>bicycle; bikini>breast; bikini>cotton; bikini>fashion; bikini>shoulder; bikini>surfing; bikini>thigh; bikini>tights; bill>bake; bill>menu; bill>police;
bill>poster; biography>literacy; biography>priest; biography>saint; biology>aggression; biology>agriculture; biology>animal; biology>bacteria; biology>cancer; biology>climate;
biology>climate change; biology>dna; biology>earth; biology>ecology; biology>energy; biology>essay; biology>evolution; biology>food; biology>gene; biology>genetics;
biology>habitat; biology>human; biology>immune system; biology>life; biology>medicine; biology>plant; biology>population; biology>protein; biology>psychology; biology>species;
bird>adaptation; bird>agriculture; bird>bacteria; bird>beak; bird>blindness; bird>cat; bird>chicken; bird>crocodile; bird>dinosaur; bird>dog; bird>dolphin; bird>duck; bird>eagle;
bird>ear; bird>evolution; bird>extinction; bird>feather; bird>heart; bird>hunting; bird>insect; bird>kidney; bird>owl; bird>parrot; bird>penguin; bird>predator; bird>reptile; bird>season;
bird>snake; bird>sound; bird>sun; bird>swan; bird>tuna; bird>wing; birth>baby; birth>birthday; birth>death; birth>health care; birth>holiday; birth>life; birth>mother; birth>nerve;
birth>offspring; birth>pregnancy; birth>sky; birth>sun; birth>surgery; birth>twins; birth>virgin; birthday>anniversary; birthday>cake; birthday>horizon; biscuit>bean; biscuit>breakfast;
biscuit>chocolate; biscuit>cookie; biscuit>cooking; biscuit>dictionary; biscuit>digestion; biscuit>flour; biscuit>sandwich; biscuit>sausage; bit>communication; bit>credit card; bit>dna;
bit>information; bit>traffic light; bite>animal; bite>bat; bite>cat; bite>dog; bite>fish; bite>food; bite>infection; bite>mouth; bite>wildlife; bite>wolf; bite>wound;
black>atom; black>blackmail; black>cherry; black>chess; black>clich  ; black>coal; black>copper; black>crime; black>darkness; black>death; black>devil; black>drawing;
black>elegance; black>evil; black>god; black>heat; black>ink; black>iron; black>leopard; black>light; black>night; black>oak; black>peach; black>physics; black>sin; black>tree;
black>white; blackboard>paint; blackboard>writing; blackmail>gossip; blackmail>robbery; blade>area; blade>bone; blade>butcher; blade>chef; blade>force; blade>hammer;

blade>knife; blade>leather; blade>machine; blade>pizza; blade>plastic; blade>predator; blade>pressure; blade>prey; blade>steel; blade>stone; blade>sword; blade>tool;
blade>toughness; blade>weapon; blade>abuse; blade>accident; blade>anxiety; blade>crime; blade>denial; blade>hierarchy; blade>organization; blade>praise;
blade>propaganda; blade>remorse; blade>safety; blade>shame; blade>shock; blade>cotton; blanket>duvet; blanket>firefighter; blanket>linen; blanket>picnic; blanket>saddle; blanket>sleep;
blanket>soil; blanket>wool; blend>dictionary; blend>root; blend>smog; blend>suiff; blindness>calculator; blindness>camera; blindness>coin; blindness>elephant; blindness>euro;
blindness>mammal; blindness>mobile phone; blindness>poverty; blindness>rabbit; blindness>tennis; blindness>thermometer; blindness>torture; blister>blood; blister>friction;
blister>skin; blog>advertising; blog>brand; blog>business; blog>corporation; blog>family; blog>forgery; blog>journalist; blog>marketing; blog>mobile phone; blog>newspaper;
blog>university; blog>web page; blog>website; blogger>blog; blood>ancestor; blood>animal; blood>antibiotic; blood>blue; blood>breath; blood>carbon dioxide; blood>carbon
monoxide; blood>copper; blood>film; blood>heat; blood>heat; blood>immune system; blood>infection; blood>injury; blood>insect; blood>iron; blood>kidney; blood>liver;
blood>lung; blood>meat; blood>mosquito; blood>oxygen; blood>protein; blood>tobacco; blood>water; blood>vein; blood>virus; blue>atmosphere; blue>basketball; blue>boy;
blue>cold; blue>colour; blue>copper; blue>denim; blue>green; blue>ice; blue>ice hockey; blue>ink; blue>jazz; blue>jeans; blue>laser; blue>oxygen; blue>pink; blue>police;
blue>red; blue>sadness; blue>sea; blue>sky; blue>sunrise; blue>sunset; blue>truth; blue>water; blue>winter; blue>yellow; blue>game>cd; board game>chess; board game>dice;
board game>diplomacy; board game>dvd; board game>email; board game>game; board game>jargon; board game>lion; board game>luck; board game>material; board
game>puzzle; board game>scenario; board game>strategy; board game>symbol; board game>website; board game>video game; board>board game; boat>aluminium;
boat>density; boat>lake; boat>navy; boat>sail; boat>ship; boat>yacht; body>arm; body>burial; body>death; body>disability; body>disease; body>health; body>human; body>insect;
body>materialism; body>meat; body>neck; body>spirit; bomb>air force; bomb>bomber; bomb>bridge; bomb>civilian; bomb>clock; bomb>construction; bomb>explosion;
bomb>friction; bomb>heat; bomb>mining; bomb>missile; bomb>parachute; bomb>port; bomb>railway; bomb>remote control; bomb>rocket; bomb>runway; bomb>temperature;
bomb>train; bomb>transport; bombing>bomb; bond>guarantee; bone>acid; bone>ankle; bone>beak; bone>birth; bone>brain; bone>coral; bone>disease; bone>evolution;
bone>exercise; bone>fat; bone>foot; bone>heart; bone>human; bone>joint; bone>kidney; bone>nerve; bone>offspring; bone>protein; bone>rib; bone>skeleton; bone>skull;
bone>structure; book>author; book>bookcase; book>business; book>cd-rom; book>controversy; book>desk; book>diary; book>dictionary; book>dvd; book>entertainment;
book>fiction; book>homework; book>ink; book>leather; book>library; book>linen; book>literacy; book>literature; book>magazine; book>map; book>market; book>meeting;
book>music; book>newspaper; book>notebook; book>novel; book>paper; book>photograph; book>prayer; book>publisher; book>punctuation; book>scientist; book>software;
book>student; book>textbook; book>word; book>writer; bookcase>book; bookcase>cupboard; bookcase>furniture; bookcase>iron; bookcase>leather; bookcase>library;
bookcase>oak; bookcase>steel; booking>arrest; booking>loan; booking>running; booking>tourism; booklet>book; bookmark>book; bookmark>fabric; bookshelf>bookcase;
boost>thief; boot>ankle; boot>blister; boot>fashion; boot>fisherman; boot>foot; boot>hip; boot>ice skating; boot>knee; boot>shoe; boot>skiing; boot>snowboarding; boot>sock;
boot>sport; boot>sweat; border>airport; border>alcohol; border>barrier; border>commerce; border>continent; border>export; border>forest; border>geography; border>government;
border>immigration; border>import; border>lake; border>ocean; border>passport; border>port; border>river; boss>leadership; boss>management; boss>supervisor; bottle>alcohol;
bottle>beer; bottle>cod; bottle>gas; bottle>ink; bottle>jar; bottle>liquid; bottle>medicine; bottle>milk; bottle>perfume; bottle>plastic; bottle>pressure; bottle>retailer;
bottle>rubber; bottle>shampoo; bottle>soft drink; bottle>water; bottle>wine; bottom>contradiction; boundary>border; bow>elbow; bow>ribbon; bow>archaeology; bowl>bar;
bowl>food; bowl>glass; bowl>metal; bowl>perfume; bowl>plastic; bowl>salad; bowl>wine; bowl>wood; box>carriage; box>circle; box>gift; box>globalization; box>letter;
box>match; box>metal; box>pizza; box>plural; box>post office; box>rectangle; box>wood; boxing>fiction; boy>angel; boy>boyfriend; boy>child; boy>choir; boy>funeral;
boy>furniture; boy>gender; boy>girl; boy>goat; boy>human; boy>infant; boy>insult; boy>male; boy>man; boy>nickname; boy>pizza; boy>portrait; boy>racist; boy>sex; boy>sheep;
boy>slang; boy>soldier; boy>teenager; boy>toddler; boy>torch; boy>trainee; boy>youth; boyfriend>girlfriend; boyfriend>marriage; boyfriend>wedding; bracelet>ankle;
bracelet>archaeology; bracelet>boot; bracelet>cloth; bracelet>hospital; bracelet>leather; bracelet>manufacturing; bracelet>metal; bracelet>necklace; bracelet>plastic;
bracket>wood; bracket>chemistry; bracket>concentration; bracket>full stop; bracket>punctuation; bracket>synonym; brain>artificial intelligence; brain>attention;
brain>digestion; brain>dog; brain>elephant; brain>evolution; brain>gene; brain>horse; brain>human; brain>insect; brain>learning; brain>medicine; brain>mind; brain>motivation;
brain>philosophy; brain>psychology; brain>rat; brain>shark; brain>stroke; brake>air; brake>anchor; brake>friction; brake>heat; brake>vehicle; brake>wheel; branch>cherry;
branch>collocation; branch>metaphor; branch>oak; branch>root; branch>synonym; branch>tree; branch>walking; brand>advertising; brand>business; brand>commodity;
brand>factory; brand>fashion; brand>industrialization; brand>logo; brand>luggage; brand>marketing; brand>personality; brand>radio; brand>slogan; brand>soap; brand>television;
brand>tide; brass>aluminium; brass>bacteria; brass>bronze; brass>coal; brass>coin; brass>dice; brass>copper; brass>glass; brass>iron; brass>lead; brass>metal;
brass>orchestra; brass>recycling; brass>tin; brass>trumpet; brass>turkey; bravery>courage; bread>baker; bread>beer; bread>biscuit; bread>bun; bread>carbon dioxide;
bread>cereal; bread>cery; bread>fat; bread>flour; bread>fruit; bread>frying pan; bread>grape; bread>meat; bread>metaphor; bread>milk; bread>money; bread>onion;
bread>oven; bread>pancake; bread>paper; bread>pizza; bread>plastic; bread>protein; bread>ratio; bread>rice; bread>sandwich; bread>sausage; bread>seed; bread>soup;
bread>spice; bread>sugar; bread>synonym; bread>temperature; bread>toast; bread>water; bread>vegetable; bread>wheat; bread>wine; bread>burglary; breakfast>bacon;
breakfast>bun; breakfast>butter; breakfast>cereal; breakfast>cheese; breakfast>chocolate; breakfast>coffee; breakfast>ham; breakfast>honey; breakfast>jam; breakfast>lunch;
breakfast>mango; breakfast>meal; breakfast>mushroom; breakfast>pancake; breakfast>sausage; breakfast>sweet; breakfast>tea; breakfast>toast; breakfast>tomato;
breakfast>yogurt; breakthrough>insight; breast>beauty; breast>cancer; breast>female; breast>infant; breast>milk; breast>nose; breast>obesity; breast>pregnancy; breast>religion;
breast>vein; breed>generation; breed>genetics; breed>offspring; breed>plant; breed>population; breed>money; breeze>wind; bribe>bribery; bribery>corporation; bribery>cricket;
bribery>donation; bribery>duty; bribery>funding; bribery>gambling; bribery>gift; bribery>medication; bribery>money; bribery>patient; bribery>police; bribery>policy; bribery>politician;
bribery>privilege; bribery>property; bribery>referee; bribery>sponsorship; brick>chimney; brick>concrete; brick>glass; brick>inch; brick>millimetre; brick>water; brick>wood;
bride>death; bride>handbag; bride>luck; bride>red; bride>spouse; bride>virgin; bride>brick; bridge>brick; bridge>laser; bridge>river; bridge>road; bridge>stream; bridge>suicide; bridge>tunnel;
bridge>turkey; bridge>valley; broadband>music; broadband>radio; broadband>telecommunications; broadband>telephone; broadband>television; broadband>video;
broccoli>bacteria; broccoli>branch; broccoli>cabbage; broccoli>cancer; broccoli>virus; brochure>paper; bronze>aluminium; bronze>blade; bronze>brass; bronze>coin;
bronze>copper; bronze>flag; bronze>friction; bronze>gold; bronze>guitar; bronze>hammer; bronze>iron; bronze>metal; bronze>oak; bronze>piano; bronze>silver; bronze>steel;
bronze>tin; bronze>toughness; brother>sibling; brother-in-law>husband; brother-in-law>sibling; brother-in-law>sister-in-law; brother-in-law>spouse; brown>autumn; brown>bear;
brown>black; brown>chocolate; brown>coffee; brown>dna; brown>humility; brown>ink; brown>iron; brown>oak; brown>rat; brown>red; brown>skin; brown>soil; brown>stone;
brown>yellow; bruise>blister; bruise>blood; bruise>blue; bruise>bone; bruise>brain; bruise>death; bruise>head; bruise>heart; bruise>lung; bruise>muscle; bruise>nerve;
bruise>pain; bruise>purple; bruise>skin; bruise>surgery; bruise>toenail; brush>artist; brush>wood; brush>camel; brush>comb; brush>copper; brush>goat; brush>hair; brush>ink; brush>paint;
brush>painting; brush>plastic; brush>pony; brush>steel; brush>toothbrush; brush>wood; bucket>beach; bucket>bronze; budget>expenses; budget>government; budget>income;
budget>project; bug>insect; building>aircraft; building>architect; building>architecture; building>construction; building>document; building>earthquake; building>electrician;
building>engineering; building>escalator; building>fire; building>funding; building>home; building>house; building>human; building>professional; building>security; building>ship;
building>storey; building>structure; building>technology; building>telecommunications; building>transport; bulb>food; bulb>garlic; bulb>leaf; bulb>onion; bulb>root; bulb>camel;
bull>cattle; bull>cow; bull>elephant; bull>god; bull>male; bull>sheep; bull>whale; bullet>brass; bullet>copper; bullet>explosive; bullet>gas; bullet>gram; bullet>lead; bullet>riot;
bullets>steel; bullet>tin; bullet>weapon; bun>bread; bun>butter; bun>flour; bun>jam; bun>milk; bun>sugar; bureaucracy>corporation; bureaucracy>transportation;
bureaucracy>writing; burglary>crime; burglary>dog; burglary>rape; burglary>theft; burglary>vandalism; burial>ancestor; burial>animal; burial>archaeology;
burial>bacteria; burial>banana; burial>bone; burial>butcher; burial>cat; burial>cemetery; burial>child; burial>construction; burial>crime; burial>culture; burial>dog;
burial>earthquake; burial>elephant; burial>flood; burial>funeral; burial>infant; burial>marriage; burial>murder; burial>ocean; burial>oven; burial>pet; burial>police; burial>religion;
burial>ritual; burial>starvation; burial>suicide; burial>temple; burial>terrorism; burial>tourism; bus station>barrier; bus station>bus stop; bus station>wheelchair; bus
stop>bus station; bus stop>dustbin; bus stop>lighting; bus stop>mobile phone; bus stop>public transport; bus>bicycle; bus>bus station; bus>bus stop; bus>camel; bus>carriage;
bus>fair; bus>paint; bus>parade; bus>passenger; bus>playground; bus>police officer; bus>procession; bus>scrap; bus>sightseeing; bus>tour guide; bus>truck; bus>wheelchair;
business>advertising; business>agriculture; business>bank; business>banking; business>capitalism; business>commerce; business>company; business>consumer;
business>corporation; business>customer; business>economics; business>economy; business>finance; business>government; business>home; business>industry;
business>insurance; business>investment; business>management; business>manufacturer; business>manufacturing; business>marketing; business>mining; business>money;
business>organization; business>partnership; business>restaurant; business>retail; business>stock market; business>trade; business>transport; business>transportation;
business>treaty; butcher>culture; butcher>manufacturing; butcher>nationality; butcher>retail; butcher>supermarket; butcher>vocation; butcher>acid; butter>beef; butter>cake;
butter>cattle; butter>cheese; butter>cholesterol; butter>cookie; butter>cooking; butter>cream; butter>dessert; butter>fat; butter>goat; butter>herb; butter>ice; butter>mammal;
butter>milk; butter>pastry; butter>peasant; butter>pie; butter>potato; butter>protein; butter>sausage; butter>saucer; butter>sheep; butter>spice; butter>sugar; butter>tea; butter>teaspoon;
butter>wine; butter>vinegar; butter>yellow; butterfly>animal; butterfly>bee; butterfly>head; butterfly>insect; butterfly>predator; butterfly>species; button>antique; button>archaeology;
button>brass; button>clothing; button>copper; button>drug; button>fabric; button>fashion; button>ink; button>linen; button>memorial; button>painting; button>plastic;
button>sculpture; button>shirt; button>wood; buyer>asset; buyer>consideration; buyer>customer; cabbage>broccoli; cabbage>cash; cabbage>pea; cabbage>selection;
cabbage>species; cabbage>tobacco; cabbage>wheat; cabin>cottage; cable>cotton; cable>fire; cable>gold; cable>rope; cable>silver; cable>tin; cable>wire; cake>anniversary;
cake>birthday; cake>bread; cake>butter; cake>chocolate; cake>dessert; cake>extract; cake>flour; cake>food; cake>milk; cake>pastry; cake>pie; cake>poet; cake>strawberry;
cake>sugar; cake>water; cake>wedding; calculator>calculator; calculator>computer; calculator>memory; calculator>statistics; calculator>student; calendar>ad;
calendar>agriculture; calendar>business; calendar>century; calendar>cheque; calendar>clock; calendar>day; calendar>decade; calendar>family; calendar>judge; calendar>lawyer;
calendar>millennium; calendar>month; calendar>night; calendar>season; calendar>sun; calendar>sunrise; calendar>sunset; calendar>tide; calendar>time; calendar>week;
calendar>year; calf>abortion; calf>auction; calf>camel; calf>cattle; calf>cow; calf>dolphin; calf>elephant; calf>farming; calf>giraffe; calf>human; calf>mammal; calf>whale;
camel>animal; camel>body; camel>butter; camel>ice cream; camel>immune system; camel>iron; camel>kidney; camel>mammal; camel>milk; camel>year; camel>yogurt;
camera>architecture; camera>digital camera; camera>image; camera>light; camera>photograph; camera>photography; camera>video; camp>campsite; camp>campus;
camp>cottage; campaign>video game; camping>air conditioning; camping>aircraft; camping>backpack; camping>bear; camping>blanket; camping>boot; camping>campsite;
camping>candle; camping>civilization; camping>climbing; camping>cold; camping>cotton; camping>electricity; camping>family; camping>fishing; camping>food;
camping>friendship; camping>frying pan; camping>hammer; camping>heat; camping>homelessness; camping>insect; camping>raincoat; camping>recreation; camping>rope;
camping>safety; camping>snow; camping>social networking; camping>tent; camping>toilet; camping>towel; camping>water; camping>wind; camping>woodland; camping>wool;
campsite>camping; campsite>electricity; campsite>hotel; campsite>picnic; campsite>road; campsite>shower; campsite>tent; campsite>vehicle; campus>college; campus>hospital;
campus>lecture; campus>library; campus>university; can>toilet; canal>agriculture; canal>bridge; canal>globalization; canal>historian; canal>infrastructure; canal>lake;
canal>ocean; canal>river; canal>ship; canal>telecommunications; canal>transport; canal>tunnel; cancer>abortion; cancer>alcohol; cancer>aspirin; cancer>bacteria; cancer>blood;
cancer>bone; cancer>coffee; cancer>cough; cancer>crab; cancer>diagnosis; cancer>disease; cancer>dna; cancer>evolution; cancer>fat; cancer>fever; cancer>gene;
cancer>immune system; cancer>infection; cancer>kidney; cancer>liver; cancer>lung; cancer>mobile phone; cancer>nerve; cancer>obesity; cancer>optimism; cancer>probability;
cancer>protein; cancer>radiation; cancer>rib; cancer>salt; cancer>smoking; cancer>sun; cancer>surgery; cancer>symptom; cancer>tobacco; cancer>vaccine; cancer>virus;
cancer>vitamin; cancer>x-ray; candidate>award; candidate>ceremony; candidate>debate; candidate>election; candidate>law; candidate>nomination; candidate>office;
candidate>official; candidate>white; candle>chemical; candle>consumer; candle>fire; candle>flame; candle>fuel; candle>honey; candle>lead; candle>light; candle>oxygen;
candle>property; candle>reach; candle>regulation; candle>religion; candle>risk; candle>safety; candle>scents; candle>standard; candle>time; capacity>volume; capital>capital letter;
capital>capitalism; capital>asset; capitalism>cattle; capitalism>coal; capitalism>commerce; capitalism>consumer; capitalism>corporation; capitalism>democracy;
capitalism>economics; capitalism>factory; capitalism>globalization; capitalism>government; capitalism>history; capitalism>incentive; capitalism>inflation; capitalism>infrastructure;
capitalism>investor; capitalism>market; capitalism>monopoly; capitalism>peasant; capitalism>policy; capitalism>recession; capitalism>slavery; capitalism>socialism;
capitalism>subsidy; capitalism>tax; capitalism>trade; capitalism>unemployment; capitalism>well-being; captain>commander; carbon dioxide>acid; carbon dioxide>alcohol; carbon
dioxide>atom; carbon dioxide>bacteria; carbon dioxide>beer; carbon dioxide>carbon; carbon dioxide>carbon monoxide; carbon dioxide>climate change; carbon dioxide>coffee;

carbon dioxide>coral; carbon dioxide>energy; carbon dioxide>fuel; carbon dioxide>gas; carbon dioxide>global warming; carbon dioxide>grape; carbon dioxide>iron; carbon dioxide>life; carbon dioxide>light; carbon dioxide>oxygen; carbon dioxide>plant; carbon dioxide>pressure; carbon dioxide>protein; carbon dioxide>soft drink; carbon dioxide>sugar; carbon dioxide>water; carbon dioxide>vein; carbon dioxide>whisky; carbon dioxide>wine; carbon dioxide>volcano; carbon dioxide>volume; carbon dioxide>wood; carbon footprint>carbon; carbon footprint>carbon dioxide; carbon footprint>coal; carbon footprint>food; carbon footprint>global warming; carbon footprint>oil; carbon monoxide>carbon; carbon monoxide>carbon dioxide; carbon monoxide>chemist; carbon monoxide>coal; carbon monoxide>headache; carbon monoxide>heart; carbon monoxide>iron; carbon monoxide>oxygen; carbon monoxide>ozone; carbon monoxide>pressure; carbon monoxide>steam; carbon monoxide>volcano; carbon acid; carbon alcohol; carbon antibiotic; carbon-art; carbon-atmosphere; carbon-atom; carbon-brush; carbon-carbon dioxide; carbon-carbon footprint; carbon-carbon monoxide; carbon-civilization; carbon-coal; carbon-commodity; carbon-cotton; carbon-crystal; carbon-density; carbon-diamond; carbon-dna; carbon-drawing; carbon-earth; carbon-electricity; carbon-electronics; carbon-fat; carbon-fuel; carbon-glass; carbon-gold; carbon-gram; carbon-human; carbon-ink; carbon-iron; carbon-kitchen; carbon-lead; carbon-leather; carbon-linen; carbon-metal; carbon-oxygen; carbon-pencil; carbon-planet; carbon-plastic; carbon-protein; carbon-pyramid; carbon-rubber; carbon-second; carbon-silk; carbon-sphere; carbon-star; carbon-sugar; carbon-sun; carbon-window; carbon-volcano; carbon-wood; carbon-writing; carbon-x-ray; card>debit card; card>postcard; care>health care; career>education; career>person; career>profession; carelessness>negligence; cargo>commerce; cargo>customs; cargo>delivery; cargo>grain; cargo>machinery; cargo>manufacturing; cargo>meat; cargo>oil; cargo>port; cargo>produce; cargo>salt; cargo>scrap; cargo>shoe; cargo>supermarket; cargo>terrorism; cargo>toy; cargo>transport; cargo>truck; cargo>van; carnival>coconut; carnival>fair; carnival>mask; carnival>parade; carnival>plan; carnival>ski; carnival>witch; carpet>cloth; carpet>commerce; carpet>cotton; carpet>linen; carpet>mat; carpet>mug; carpet>nature; carpet>sewing; carpet>silk; carpet>turkey; carpet>wool; carriage>bride; carriage>bus; carriage>groom; carriage>horse; carriage>pony; carriage>sightseeing; carriage>tourism; carriage>turkey; carrot>fat; carrot>fruit; carrot>jam; carrot>onion; carrot>snack; carrot>soup; carrot>sugar; carrot>supermarket; cartoon>animation; cartoon>drawing; cartoon>illustration; cartoon>irony; cartoon>painting; cartoon>paper; case>bookcase; case>box; case>suitcase; cash>bank; cash>coin; cash>currency; cash>finance; cash>inflation; cash>money; casserole>beer; casserole>flour; casserole>oven; casserole>pasta; casserole>potato; casserole>rice; casserole>wine; cast>archaeology; cast>fantasy; castle>archaeology; castle>headquarters; castle>palace; casualty>disaster; cat>animal; cat>aspirin; cat>bird; cat>camel; cat>dream; cat>fur; cat>giraffe; cat>grass; cat>leopard; cat>mammal; cat>paw; cat>pet; cat>rat; cat>scissors; cat>tongue; catastrophe>disaster; catering>business; catering>concert; catering>drink; catering>wedding; catering>vegetarian; catering>vehicle; cathedral>chapel; cathedral>earth; cathedral>heaven; cathedral>sculpture; cattle>agriculture; cattle>animal; cattle>beef; cattle>blood; cattle>bull; cattle>butter; cattle>camel; cattle>cheese; cattle>clothing; cattle>contract; cattle>elephant; cattle>fence; cattle>fuel; cattle>global warming; cattle>heart; cattle>herb; cattle>horse; cattle>kidney; cattle>leather; cattle>liver; cattle>mammal; cattle>meat; cattle>milk; cattle>plural; cattle>shoe; cattle>species; cattle>sport; cattle>stomach; cattle>tick; cattle>transport; cattle>turkey; cattle>vegetation; cattle>whale; cattle>yogurt; cave>bat; cd player>cd; cd player>computer; cd player>consumer; cd player>dj; cd player>sound; cd-rom>aluminium; cd-rom>dvd; cd-rom>laser; cd-rom>minute; cd-rom>plastic; cd-rom>second; cd-rom>software; cd-rom>video game; ceiling>cathedral; ceiling>concrete; ceiling>system; celebration>festival; celebration>holiday; celebration>party; celebrity>entertainer; celebrity>fragrance; celebrity>leader; celebrity>medication; celebrity>monster; celebrity>nightclub; celebrity>pottery; celebrity>presenter; celebrity>referee; celebrity>reporter; celebrity>social networking; celebrity>soft drink; celebrity>spy; cell>mobile phone; cellar>basement; cello>disco; cello>guitar; cello>hip-hop; cello>jazz; cello>length; cello>orchestra; cello>piano; cello>plastic; cello>steel; cello>violin; cello>volume; cemetery>angel; cemetery>angel; cemetery>brick; cemetery>burial; cemetery>concrete; cemetery>crime; cemetery>culture; cemetery>flower; cemetery>funeral; cemetery>grass; cemetery>lawn; cemetery>legend; cemetery>legislation; cemetery>map; cemetery>metal; cemetery>monument; cemetery>profession; cemetery>religion; cemetery>skeleton; cemetery>timber; cemetery>tomb; cemetery>toy; cemetery>vase; cent>century; centimetre>equal; centimetre>inch; centimetre>length; centimetre>litre; centimetre>metre; centimetre>millimetre; central heating>air conditioning; central heating>climate; central heating>dishwasher; central heating>grape; central heating>heating; central heating>pump; central heating>washing machine; century>decade; century>millennium; century>year; cereal>agriculture; cereal>fat; cereal>fruit; cereal>protein; cereal>rice; cereal>wheat; cereal>vitamin; ceremony>battle; ceremony>birthday; ceremony>burial; ceremony>dance; ceremony>death; ceremony>funeral; ceremony>gift; ceremony>procession; ceremony>retirement; ceremony>ritual; ceremony>theatre; ceremony>wedding; certainty>belief; certainty>doubt; certainty>instinct; certainty>paradox; certainty>philosophy; certainty>uncertainty; chain>dimension; chain>liberty; chain>toilet; chair>cushion; chair>furniture; chair>leather; chair>oak; chair>privacy; chair>public transport; chair>saddle; chair>seat; chair>throne; chair>wheelchair; chair>wood; champagne>carbon dioxide; champion>championship; champion>competition; champion>victory; championship>boxing; championship>champion; championship>sport; championship>tennis; chance>luck; chance>probability; chancellor>parliament; chancellor>prime minister; chancellor>solicitor; chancellor>title; change>coin; channel>canal; chapel>cathedral; chapel>college; chapel>hospital; chapel>palace; chapel>prayer; chapel>prison; chapel>room; chapel>ship; chapel>worship; characteristic>entity; characteristic>property; charge>debit; charm>charisma; chart>data; chart>diagram; chart>genetics; chart>graphics; chart>map; chart>number; chart>percentage; chart>symbol; chat>cat; chat>conversation; check>cheque; check>chin; check>dna; check>ear; check>face; check>individual; check>jaw; check>mammal; check>mouth; check>species; cheerfulness>happiness; cheese>acid; cheese>agriculture; cheese>butter; cheese>cattle; cheese>cow; cheese>fat; cheese>fortnight; cheese>garlic; cheese>goat; cheese>headache; cheese>herb; cheese>legend; cheese>milk; cheese>nightmare; cheese>pizza; cheese>protein; cheese>rash; cheese>sheep; cheese>spice; cheese>vinegar; cheese>world; chef>butcher; chef>fish; chef>kitchen; chef>meat; chef>profession; chef>salad; chef>sauce; chef>vegetable; chemist>alcohol; chemist>atom; chemist>chemistry; chemist>fire; chemist>glass; chemist>gold; chemist>iron; chemist>medication; chemist>pharmacist; chemist>physics; chemist>scientist; chemist>structure; chemist>acid; chemistry>atom; chemistry>biology; chemistry>carbon; chemistry>carbon dioxide; chemistry>concentration; chemistry>concept; chemistry>crystal; chemistry>density; chemistry>diamond; chemistry>drug; chemistry>electricity; chemistry>energy; chemistry>experiment; chemistry>force; chemistry>gas; chemistry>genetics; chemistry>geology; chemistry>heat; chemistry>hypothesis; chemistry>iron; chemistry>laboratory; chemistry>liquid; chemistry>matter; chemistry>observation; chemistry>oxygen; chemistry>particle; chemistry>physics; chemistry>pressure; chemistry>solution; chemistry>structure; chemistry>temperature; chemistry>tin; chemistry>volume; cheque>cash; cheque>credit card; cheque>debit card; cheque>drawer; cheque>payment; cherry>flower; cherry>fruit; cherry>turkey; cherry>vitamin; chess>aggression; chess>board game; chess>dice; chess>intelligence; chess>knowledge; chess>mobile phone; chess>perception; chess>of drawers>bedroom; chess>of drawers>clothing; chess>of drawers>furniture; chess>of drawers>mirror; chess>of drawers>oak; chess>of drawers>underwear; chess>of drawers>wood; chess>breast; chess>cancer; chess>cough; chess>digestion; chess>heart; chess>infection; chess>kidney; chess>neck; chess>shoulder; chess>stomach; chess>tobacco; chess>x-ray; chewing gum>bacteria; chewing gum>bark; chewing gum>culture; chewing gum>grass; chewing gum>plant; chewing gum>rubber; chewing gum>stomach; chewing gum>tree; chicken>agriculture; chicken>animal; chicken>beard; chicken>bird; chicken>breed; chicken>death; chicken>devil; chicken>extinction; chicken>fast food; chicken>fat; chicken>feather; chicken>god; chicken>leg; chicken>lion; chicken>man; chicken>meat; chicken>pet; chicken>pig; chicken>pork; chicken>pottery; chicken>recipe; chicken>silk; chicken>stomach; chicken>theatre; chicken>tick; chicken>wedding; chicken>vegetarian; chicken>woman; child>abortion; child>birth; child>childhood; child>daughter; child>human; child>infancy; child>son; childhood>birth; childhood>cat; childhood>child; childhood>culture; childhood>historian; childhood>human rights; childhood>infant; childhood>innocence; childhood>jail; childhood>park; childhood>playground; childhood>television; childhood>toddler; childhood>violin; chill>temperature; chimney>castle; chimney>central heating; chimney>concrete; chimney>density; chimney>earthquake; chimney>fireplace; chimney>fuel; chimney>lead; chimney>mobile phone; chimney>pressure; chimney>smoke; chimney>tv; chin>elephant; chin>face; chin>speech; chip>paint; chocolate>cherry; chocolate>cholesterol; chocolate>food; chocolate>obesity; chocolate>sweet; choice>abortion; choice>availability; choice>convenience; choice>economy; choice>emotion; choice>feeling; choice>image; choice>nutrition; choice>preference; choice>tradition; choir>harmony; choir>opera; choir>orchestra; choir>piano; choir>trumpet; cholesterol>beef; cholesterol>cancer; cholesterol>cheese; cholesterol>chemical; cholesterol>fish; cholesterol>liver; cholesterol>medication; cholesterol>peanut; cholesterol>pork; cholesterol>protein; cholesterol>stroke; cholesterol>suffix; cholesterol>thermometer; cholesterol>water; church>institution; church>religion; cigarette>blend; cigarette>brand; cigarette>cancer; cigarette>debit card; cigarette>prince; cigarette>smoking; cigarette>stroke; cigarette>tobacco; cigarette>turkey; circle>astronomy; circle>arc; circle>curve; circle>equation; circle>gear; circle>science; circle>shape; circle>sphere; circle>triangle; circus>wheel; circulation>circus; circus>bear; circus>bird; circus>clown; circus>elephant; circus>gymnastics; circus>horse; circus>television; city>agriculture; city>bank; city>cathedral; city>civilization; city>communication; city>county; city>crime; city>democracy; city>empire; city>employment; city>finance; city>firm; city>history; city>homelessness; city>house; city>industry; city>market; city>mayor; city>pollution; city>rain; city>recreation; city>religion; city>suburb; city>sunlight; city>tourist; city>town; city>trade; city>traffic; city>transportation; city>waste; city>village; civilian>country; civilian>crew; civilian>passenger; civilian>terrorism; civilization>agriculture; civilization>architecture; civilization>bureaucracy; civilization>city; civilization>climate change; civilization>complexity; civilization>culture; civilization>currency; civilization>education; civilization>elite; civilization>globalization; civilization>government; civilization>grain; civilization>hierarchy; civilization>law; civilization>literacy; civilization>market; civilization>materialism; civilization>measurement; civilization>money; civilization>ownership; civilization>priest; civilization>religion; civilization>science; civilization>society; civilization>sustainability; civilization>technology; civilization>trade; civilization>transportation; civilization>tribe; civilization>tribute; civilization>university; civilization>writing; claim>proposition; claim>right; clash>battle; class>classroom; class>lesson; classic>adjective; classic>antique; classic>masterpiece; classic>noun; classroom>biology; classroom>book; classroom>chart; classroom>chemistry; classroom>daylight; classroom>desk; classroom>furniture; classroom>gym; classroom>learning; classroom>lecture; classroom>map; classroom>physics; classroom>room; classroom>teacher; classroom>teaching; classroom>tv; classroom>university; clause>gerund; clause>grammar; clause>proposition; clause>verb; cleaner>bucket; cleaner>payment; cleaner>towel; cliché>cartoon; cliché>fact; cliché>idiom; cliché>stereotype; click>animation; client>customer; cliff>channel; cliff>climbing; cliff>coast; cliff>earth; cliff>erosion; cliff>geology; cliff>mountain; cliff>river; cliff>soil; cliff>waterfall; climate change>cloud; climate change>energy; climate change>fish; climate change>global warming; climate change>island; climate change>satellite; climate change>sun; climate change>sunlight; climate change>weather; climate change>vegetation; climate change>volcano; climate>atmosphere; climate>carbon dioxide; climate>climate change; climate>continent; climate>desert; climate>earth; climate>global warming; climate>history; climate>ice; climate>landscape; climate>mammal; climate>ocean; climate>planet; climate>storm; climate>sun; climate>temperature; climate>thermometer; climate>thunderstorm; climate>weather; climate>wind; climate>world; climate>abortion; clinic>hospital; clinic>surgery; clinic>x-ray; clock>alarm clock; clock>atom; clock>blindness; clock>central heating; clock>counter; clock>day; clock>earthquake; clock>electronics; clock>energy; clock>feedback; clock>friction; clock>gear; clock>hour; clock>invention; clock>minute; clock>mobile phone; clock>mp3 player; clock>sand; clock>second; clock>time; clock>watch; clock>year; clothes>clothing; clothing>bandage; clothing>button; clothing>cap; clothing>carpet; clothing>climate; clothing>culture; clothing>diving; clothing>fashion; clothing>film; clothing>fur; clothing>gender; clothing>globalization; clothing>glove; clothing>gymnastics; clothing>handbag; clothing>hat; clothing>hygiene; clothing>infant; clothing>insect; clothing>ironing; clothing>jeans; clothing>laundry; clothing>leather; clothing>painting; clothing>paper; clothing>peer pressure; clothing>photo; clothing>professional; clothing>religion; clothing>shirt; clothing>shorts; clothing>skiing; clothing>skirt; clothing>surfing; clothing>sweater; clothing>television; clothing>tracksuit; clothing>trousers; clothing>t-shirt; clothing>washing machine; clothing>weather; clothing>whale; clothing>wind; clothing>winter; clothing>yellow; cloud>atmosphere; cloud>bacteria; cloud>chemical; cloud>climate; cloud>crystal; cloud>energy; cloud>evolution; cloud>feedback; cloud>fog; cloud>global warming; cloud>habitat; cloud>hail; cloud>light; cloud>lightning; cloud>liquid; cloud>mist; cloud>mountain; cloud>planet; cloud>rain; cloud>salt; cloud>snow; cloud>stable; cloud>summer; cloud>sun; cloud>symbol; cloud>temperature; cloud>thunderstorm; cloud>tornado; cloud>water; cloud>weather; cloud>winter; clown>comedy; clown>donkey; clown>elephant; clown>horse; clown>orchestra; clown>performer; clown>priest; clown>psychology; clown>zebra; club>basketball; club>boxing; club>exercise; club>golf; club>gym; club>secondary school; clue>evidence; clutch>air conditioning; clutch>cable; clutch>friction; clutch>machine; clutch>pressure; coach>coaching; coaching>career; coaching>consultant; coaching>consumer; coaching>discussion; coaching>fashion; coaching>inquiry; coaching>leadership; coaching>marriage; coaching>psychology; coaching>recreation; coal>carbon; coal>carbon dioxide; coal>carbon monoxide; coal>climate change; coal>funeral; coal>global warming; coal>iron; coal>oxygen; coal>pressure; coal>steam; coal>steel; coal>world; coast>animal; coast>bay; coast>beach; coast>canal; coast>circle; coast>cliff; coast>climate change; coast>coral; coast>dolphin; coast>erosion; coast>fishing; coast>flood; coast>house; coast>infrastructure; coast>insect; coast>island; coast>lake; coast>navy; coast>ocean; coast>plant; coast>pond; coast>port; coast>rubble; coast>salt; coast>sea; coast>shore; coast>solution; coast>surfing; coast>tide; coast>transport; coast>wave; coast>weather; coastline>coast; coast>paint; coat>skin; coconut>butterfly; coconut>carpet; coconut>flower; coconut>fruit; coconut>ghost; coconut>plant; coconut>seed; coconut>soap; coconut>theatre; coconut>witch; cod>beard; cod>scrab; cod>export; cod>food; cod>heart; cod>species; cod>worm; code>biology; code>bit; code>chess; code>communication; code>computer; code>data; code>dna; code>gesture; code>information; code>journalism; code>language; code>length; code>marketing; code>music; code>phrase; code>sign; code>word; coffee>climate change; coffee>corn; coffee>headache; coffee>illness; coffee>liver; coffee>milk; coffee>rice; coffee>shade; coffee>sugar; coffee>tea; coffee>turkey; coffee>wine; coffee>worm; coin>copper; coin>currency; coin>deer; coin>dice; coin>euro; coin>exchange rate; coin>gold; coin>inflation; coin>money; coin>penny; coin>silver; coincidences>earth; coincidences>genius; coincidences>paradox; coincidences>probability; coincidences>science; coincidences>statistics; coincidences>sun; cola>lemon; cola>pharmacist; cola>soft drink;

cold>air; cold>atmosphere; cold>earth; cold>energy; cold>freezer; cold>frost; cold>hail; cold>heat; cold>ice; cold>ice cream; cold>iceberg; cold>mammal; cold>physics; cold>radiation; cold>snow; cold>sun; cold>temperature; cold>winter; coldness>cold; collaboration>ballet; collaboration>blog; collaboration>business; collaboration>community; collaboration>computer; collaboration>cooperation; collaboration>industry; collaboration>leadership; collaboration>medicine; collaboration>organization; collaboration>partnership; collaboration>piano; collaboration>socialism; collaboration>trade; collaboration>violin; collar>arrest; collar>slave; college>law; college>secondary school; college>university; college>vocation; collocation>cliché; collocation>grammar; collocation>idiom; collocation>phrasal verb; column>arch; column>architecture; column>relief; comb>hair; comb>metaphor; comb>perfume; comb>police; comb>tool; comb>assault; comb>kick; comb>knife; comb>law; comb>sword; comb>synonym; comb>war; comb>weapon; comb>violence; combination>probability; comeback>politics; comedian>comedy; comedian>humour; comedian>joke; comedian>laughter; comedy>clown; comedy>evil; comedy>film; comedy>humour; comedy>irony; comedy>laughter; comedy>literature; comedy>television; comedy>theatre; comedy>tragedy; comedy>word; comfort>health care; comfort>memory; comfort>pain; comfort>pleasure; comfort>suffering; comma>apostrophe; comma>clause; comma>full stop; comma>grammar; comma>punctuation; comma>semicolon; commander>army; commander>inspector; commerce>advertising; commerce>agriculture; commerce>business; commerce>capitalism; commerce>cargo; commerce>coin; commerce>communication; commerce>corporation; commerce>currency; commerce>economics; commerce>export; commerce>fair; commerce>finance; commerce>globalization; commerce>gold; commerce>harvest; commerce>import; commerce>industry; commerce>manufacturing; commerce>market; commerce>marketing; commerce>money; commerce>trade; commercial>advertising; commercial>commerce; commercial>trade; commitment>brand; commitment>contract; commitment>promise; committee>research; committee>secretary; commodity>agriculture; commodity>brand; commodity>coal; commodity>coffee; commodity>copper; commodity>economics; commodity>gold; commodity>inflation; commodity>market; commodity>mining; commodity>price; commodity>rice; commodity>salt; commodity>silver; commodity>sugar; commodity>tea; commodity>trade; commodity>wheat; common sense>artificial intelligence; common sense>idea; common sense>logic; common sense>philosopher; common sense>relevance; common sense>wisdom; communication>architecture; communication>bacteria; communication>clothing; communication>collaboration; communication>conversation; communication>cooperation; communication>dialect; communication>diary; communication>feedback; communication>gesture; communication>grammar; communication>human; communication>information; communication>jargon; communication>message; communication>name; communication>noise; communication>plant; communication>rhythm; communication>soil; communication>sound; communication>symbol; communication>system; communication>writing; community>archaeology; community>belief; community>biology; community>city; community>communication; community>competition; community>construction; community>content; community>culture; community>disability; community>ecology; community>economics; community>family; community>festival; community>home; community>human; community>individual; community>intensity; community>intention; community>life; community>nation; community>neighbourhood; community>office; community>politics; community>preference; community>risk; community>role; community>selfishness; community>suburb; community>town; community>village; companion>friendship; company>bank; company>corporation; company>desire; company>duty; company>duty; company>goal; company>law; company>partnership; company>person; company>policy; company>resource; company>skill; comparative>advertising; comparative>suburb; comparative>superlative; competence>skill; competition>adaptation; competition>award; competition>baseball; competition>basketball; competition>biology; competition>brand; competition>budget; competition>celebrity; competition>championship; competition>civilization; competition>consumer; competition>cooperation; competition>cost; competition>country; competition>cricket; competition>culture; competition>democracy; competition>diving; competition>ecology; competition>election; competition>evolution; competition>extinction; competition>fishing; competition>food; competition>football; competition>funding; competition>government; competition>gymnastics; competition>income; competition>investor; competition>law; competition>monopoly; competition>nationality; competition>nature; competition>philosopher; competition>politics; competition>pride; competition>psychologist; competition>psychology; competition>recreation; competition>self-esteem; competition>sunlight; competition>tax; competition>tennis; competition>war; competition>water; competition>wealth; competition>competition; complaint>birthday; complaint>definition; complaint>lawyer; complex>building; complex>complexity; complex>biology; complex>dna; complex>fluid; complex>racism; complex>skin; complex>therapy; complexity>biology; complexity>dimension; complexity>economics; complexity>feedback; complexity>observation; complexity>probability; complexity>property; complexity>science; complexity>simplicity; complexity>simulation; complexity>stock market; complexity>system; complexity>technology; component>ingredient; component>system; composer>arrangement; composer>jazz; composer>music; composer>musician; composer>performance; composer>performer; composer>song; compromise>acceptance; compromise>argument; compromise>communication; compromise>constitution; compromise>demand; computer>artificial intelligence; computer>bit; computer>bunch; computer>calculator; computer>commodity; computer>electronics; computer>icon; computer>laptop; computer>microphone; computer>programmer; computer>spreadsheet; computer>washing machine; computer>webcam; computer>video game; computer>wire; concentration>chemistry; concentration>solution; concept>idea; concept>learning; concept>logic; concept>man; concept>memory; concept>philosophy; concept>psychology; concept>skill; conception>concept; concern>worry; concert>audience; concert>choir; concert>dancing; concert>house; concert>jazz; concert>music; concert>musician; concert>nightclub; concert>orchestra; concert>performance; concert>rehearsal; concert>singer; concert>stadium; conclusion>result; concrete>arch; concrete>boat; concrete>carbon dioxide; concrete>chemistry; concrete>construction; concrete>fence; concrete>parking; concrete>sand; concrete>sugar; concrete>water; conference>meeting; confession>ritual; confession>sin; confidence>faith; confidence>police; confidence>security; confidence>self-confidence; confidence>shyness; confidence>synonym; confirmation>faith; confirmation>prayer; confirmation>priest; confirmation>saint; conscience>abortion; conscience>advertising; conscience>aggression; conscience>animal; conscience>artificial intelligence; conscience>authority; conscience>bird; conscience>brain; conscience>carbon footprint; conscience>chess; conscience>climate change; conscience>consciousness; conscience>consumer; conscience>contempt; conscience>culture; conscience>democracy; conscience>dignity; conscience>earth; conscience>ecology; conscience>evil; conscience>famine; conscience>fear; conscience>generosity; conscience>genetics; conscience>god; conscience>human rights; conscience>integrity; conscience>intellect; conscience>intelligence; conscience>justice; conscience>legislation; conscience>materialism; conscience>matter; conscience>mind; conscience>murder; conscience>parliament; conscience>philosophy; conscience>physics; conscience>politics; conscience>pride; conscience>propaganda; conscience>psychology; conscience>racism; conscience>reason; conscience>religion; conscience>remorse; conscience>self-awareness; conscience>shame; conscience>sin; conscience>society; conscience>sustainability; conscience>torture; conscience>truth; conscience>war; conscience>violence; consciousness>adaptation; consciousness>artificial intelligence; consciousness>awareness; consciousness>computer; consciousness>conscience; consciousness>dream; consciousness>experience; consciousness>explanation; consciousness>feeling; consciousness>information; consciousness>knowledge; consciousness>language; consciousness>medicine; consciousness>memory; consciousness>mind; consciousness>perception; consciousness>philosophy; consciousness>psychology; consciousness>robot; consciousness>self; consciousness>self-awareness; consciousness>sleep; consciousness>stroke; consciousness>validity; consent>crime; consent>excuse; consent>rape; consent>signature; consequence>punishment; conservation>sustainability; consideration>contract; consideration>legislation; consonant>alphabet; consonant>syllable; consonant>symbol; consonant>vowel; constitution>democracy; constitution>human rights; constitution>institution; constitution>liberty; constitution>parliament; constitution>precedent; constitution>president; constitution>prime minister; constitution>referendum; constitution>revolution; constitution>treaty; construction>accountant; construction>architect; construction>architecture; construction>budget; construction>building; construction>career; construction>consultant; construction>contract; construction>craft; construction>drawing; construction>electrician; construction>engineer; construction>fraud; construction>infrastructure; construction>planning; construction>plumber; construction>profession; construction>project; construction>supervisor; construction>vocation; consultant>engineering; consultant>finance; consultant>law; consultant>management; consultant>marketing; consultant>professional; consultant>surgery; consumer>business; consumer>commodity; consumer>household; consumer>individuality; consumer>marketing; consumption>consumer; container>bottle; container>box; container>jar; container>pottery; contempt>anger; contempt>disgust; contempt>prostitute; contempt>resentment; contents>content; contest>competition; contestant>celebrity; contestant>competition; contestant>professional; contestant>television; continent>earth; continent>geology; continent>island; continent>ocean; continent>volcano; contract>commerce; contract>consideration; contract>country; contract>belief; contract>employment; contract>fraud; contract>legislation; contract>negotiation; contract>pacifist; contract>patient; contract>promise; contract>theatre; contradiction>belief; contradiction>capitalism; contradiction>irony; contradiction>paradox; contradiction>proposition; contradiction>socialism; contradiction>system; contradiction>truth; contribution>donation; contribution>payment; contribution>publication; control>self-control; controversy>argument; controversy>celebrity; controversy>climate change; controversy>crime; controversy>culture; controversy>economics; controversy>education; controversy>finance; controversy>gender; controversy>global warming; controversy>history; controversy>information; controversy>opinion; controversy>organization; controversy>philosophy; controversy>politics; controversy>religion; controversy>science; controversy>science fiction; controversy>sex; controversy>society; convenience>consumer; convenience>electricity; convenience>energy; convenience>frustration; convenience>money; convenience>petrol; convenience>technology; convenience>time; convention>treaty; conversation>communication; conversation>criticism; conversation>dialogue; conversation>gossip; conversation>humour; conversion>exchange rate; conviction>appeal; conviction>crime; conviction>law; conviction>punishment; conviction>verdict; cook>cooking; cookie>biscuit; cookie>bun; cookie>butter; cookie>cake; cookie>carbon dioxide; cookie>chocolate; cookie>fat; cookie>flour; cookie>fruit; cookie>jam; cookie>milk; cookie>pastry; cookie>sandwich; cookie>spice; cookie>sugar; cooking>bacon; cooking>bakery; cooking>barbecue; cooking>berry; cooking>broccoli; cooking>carbon; cooking>cereal; cooking>food; cooking>frying pan; cooking>meal; cooking>muscle; cooking>nutrition; cooking>olive; cooking>pottery; cooking>protein; cooking>recipe; cooking>sauce; cooking>seed; cooking>spice; cooking>spinach; cooking>wine; cooperation>collaboration; cooperation>emotion; cooperation>language; cooperation>teamwork; copper>aluminium; copper>brass; copper>bronze; copper>carbon monoxide; copper>dna; copper>door; copper>electronics; copper>glass; copper>gold; copper>mining; copper>silver; copper>telecommunications; copper>tin; copper>toilet; coral>animal; coral>canal; coral>carbon dioxide; coral>fish; coral>geology; coral>ocean; coral>pollution; coral>species; coral>tide; core>seed; corporation>business; corporation>company; corporation>contract; corporation>crime; corporation>employment; corporation>fraud; corporation>human rights; corporation>partnership; corporation>spice; correction>punishment; corridor>hall; corruption>blackmail; corruption>bribe; corruption>bribery; corruption>budget; corruption>discretion; corruption>fraud; corruption>liability; corruption>organization; corruption>philosophy; corruption>theft; cost>advertising; cost>business; cost>economics; cost>expense; cost>manufacturing; cost>money; cost>paradigm; cost>personnel; cost>price; cost>research; cost>retail; costume>beard; costume>clothing; costume>exile; costume>performance; costume>picture; costume>poem; costume>statue; costume>theatre; cottage>acre; cottage>fishing; cottage>mining; cottage>sailing; cotton>bacteria; cotton>denim; cotton>export; cotton>frost; cotton>import; cotton>jeans; cotton>protein; cotton>soil; cotton>subsidy; cotton>tent; cotton>t-shirt; cotton>underwear; cotton>water; cotton>wool; cough>bacteria; cough>insomnia; cough>lung; cough>smoking; cough>virus; council>city; council>committee; council>county; council>government; council>town; count>country; count>language; count>pair; count>palace; counter>electronics; counter>ratio; country>count; country>indefinite article; country>nation; country>synonym; county>burial; county>city; county>count; county>country; county>hospital; county>magistrate; county>province; county>region; county>tax; county>town; county>village; courage>fear; courage>hero; courage>lion; courage>love; courage>pain; courage>psychology; courage>religion; courage>risk; courage>scandal; courage>shame; courage>uncertainty; courage>virtue; course>main course; court>appeal; court>authority; court>constitution; court>government; court>institution; court>judge; court>law; court>lawyer; court>trial; courtesy>conversation; courtesy>elegance; courtesy>intellectual; courtesy>kindness; courtesy>politeness; cousin>family; cousin>generation; cousin>grandparent; cousin>parent; cousin>sibling; cow>cattle; coverage>insurance; coverage>news; crab>animal; crab>bacteria; crab>predator; crab>shore; crab>species; crab>tail; crab>tide; crab>worm; crackdown>cartoon; crackdown>police; crackdown>video game; craft>agriculture; craft>customer; craft>education; craft>fair; craft>glass; craft>industry; craft>material; craft>metal; craft>paper; craft>profession; craft>professional; craft>relief; craft>science; craft>skill; craft>trade; craft>tradition; craft>vocation; craft>wood; craft>workshop; crash>linen; crash>sleep; cream>air; cream>bacteria; cream>butter; cream>cattle; cream>cheese; cream>coffee; cream>honey; cream>ice cream; cream>milk; cream>plant; cream>sauce; cream>soup; cream>wine; creation>art; creation>invention; creativity>analogy; creativity>architecture; creativity>art; creativity>artificial intelligence; creativity>collaboration; creativity>design; creativity>economics; creativity>economist; creativity>education; creativity>engineering; creativity>evolution; creativity>existence; creativity>fair; creativity>genius; creativity>greatness; creativity>imagination; creativity>innovation; creativity>insight; creativity>intelligence; creativity>invention; creativity>language; creativity>literature; creativity>metaphor; creativity>music; creativity>philosophy; creativity>psychology; creativity>resource; creativity>revelation; creativity>science; creativity>supervisor; creativity>technology; creativity>theory; creativity>threat; creativity>wealth; creature>life; credibility>integrity; credibility>witness; credit card>cash; credit card>cheque; credit card>college; credit card>consumer; credit card>debit card; credit card>debt; credit card>electronics; credit card>expense; credit card>forgery; credit card>fuel; credit card>interest; credit card>metal; credit card>payment; credit card>receipt; credit card>signature; credit card>tax; credit card>tuition; credit card>credibility; crew>airline; crew>hierarchy; crew>sport; crew>team; cricket>baseball; cricket>hockey; cricket>law; crime>alcohol; crime>arrest; crime>assault; crime>civilization; crime>commerce; crime>consensus; crime>country; crime>creativity; crime>crisis; crime>culture; crime>definition; crime>economics; crime>employer; crime>employment;

crime>family; crime>fear; crime>gambling; crime>government; crime>imprisonment; crime>justice; crime>king; crime>law; crime>liberty; crime>logic; crime>murder; crime>paradox; crime>payment; crime>police; crime>politics; crime>population; crime>psychology; crime>punishment; crime>rape; crime>reason; crime>religion; crime>revenge; crime>robbery; crime>sin; crime>slavery; crime>society; crime>statistics; crime>theft; crime>treaty; crime>trial; crime>war; criminal>crime; crisis>affair; crisis>combat; crisis>disaster; crisis>earthquake; crisis>hazard; crisis>health; crisis>homelessness; crisis>probability; crisis>recession; crisis>revolution; crisis>security; crisis>self-esteem; crisis>species; crisis>threat; crisis>war; critic>analysis; critic>complaint; critic>review; criticism>ambiguity; criticism>authority; criticism>complaint; criticism>controversy; criticism>criminal; criticism>denial; criticism>denial; criticism>hypocrisy; criticism>noun; criticism>prejudice; criticism>protest; criticism>self-esteem; criticism>terrorist; criticism>verb; crocodile>aggression; crocodile>bind; crocodile>bite; crocodile>carbon dioxide; crocodile>cold; crocodile>deer; crocodile>dinosaur; crocodile>dna; crocodile>ecology; crocodile>evolution; crocodile>extinction; crocodile>fish; crocodile>foot; crocodile>handbag; crocodile>heart; crocodile>helicopter; crocodile>hierarchy; crocodile>lake; crocodile>mammal; crocodile>measurement; crocodile>muscle; crocodile>nest; crocodile>nostril; crocodile>predator; crocodile>reproduction; crocodile>reptile; crocodile>river; crocodile>shark; crocodile>skull; crocodile>species; crocodile>tongue; crocodile>agriculture; crocodile>animal; crocodile>bacteria; crocodile>clothing; crocodile>cotton; crocodile>farming; crocodile>food; crocodile>harvest; crocodile>human; crocodile>milk; crocodile>mushroom; crocodile>pet; crocodile>plant; crocodile>potato; crocodile>rice; crocodile>species; crocodile>wheat; crocodile>yogurt; crocodile>addition; crocodile>anchor; crocodile>era; crocodile>firefighter; crocodile>fork; crocodile>life; crocodile>world; crowd>bird; crowd>shopping; cruelty>divorce; cruelty>law; cruelty>pleasure; cruelty>punishment; cruelty>suffering; cruelty>torture; cruelty>violence; crystal>atom; crystal>carbon; crystal>diamond; crystal>glass; crystal>ice; crystal>liquid; crystal>metal; crystal>salt; crystal>snow; crystal>temperature; cucumber>agriculture; cucumber>bean; cucumber>plant; cucumber>spice; cucumber>turkey; cucumber>vegetable; cucumber>vinegar; cultivation>spirit; culture>agriculture; culture>archaeology; culture>architecture; culture>art; culture>capitalism; culture>child; culture>civilization; culture>commerce; culture>communication; culture>cow; culture>dialect; culture>education; culture>elite; culture>evolution; culture>experience; culture>fashion; culture>festival; culture>film; culture>gender; culture>globalization; culture>history; culture>holiday; culture>human; culture>language; culture>literature; culture>mother; culture>music; culture>myth; culture>nationality; culture>polarization; culture>philosophy; culture>photography; culture>psychology; culture>religion; culture>ritual; culture>society; culture>statistics; culture>symbol; culture>technology; culture>tool; culture>tradition; cup>trophy; cupboard>central heating; cupboard>dirty; cupboard>dust; cupboard>food; cupboard>linen; cupboard>towel; cupboard>wood; cure>cancer; cure>disease; cure>medication; cure>surgery; cure>symptom; cure>therapy; curiosity>animal; curiosity>attention; curiosity>cat; curiosity>death; curiosity>emotion; curiosity>exploration; curiosity>happiness; curiosity>human; curiosity>infancy; curiosity>instinct; curiosity>learning; curiosity>memory; curiosity>motivation; curiosity>violence; currency>bank; currency>banking; currency>cash; currency>cheque; currency>coin; currency>copper; currency>debt; currency>dollar; currency>euro; currency>exchange rate; currency>inflation; currency>loan; currency>money; currency>monopoly; currency>receipt; currency>stock; currency>treaty; curriculum>adult; curriculum>child; curriculum>college; curriculum>definition; curriculum>education; curriculum>idea; curriculum>knowledge; curriculum>lesson; curriculum>reality; curriculum>school; curriculum>society; curriculum>syllabus; curriculum>teaching; curriculum>university; curry>apple; curry>banana; curry>beef; curry>bread; curry>butter; curry>carrot; curry>coconut; curry>cream; curry>dinner; curry>garlic; curry>herb; curry>honey; curry>lunch; curry>onion; curry>pork; curry>potato; curry>rice; curry>spice; curry>tuna; curry>vegetable; curry>vegetarian; curry>wheat; curry>wine; curry>yogurt; curtain>button; curtain>cloth; curtain>department store; curtain>door; curtain>knot; curtain>light; curtain>night; curtain>retail; curtain>rope; curtain>rubber; curtain>sleep; curtain>theatre; curtain>water; curtain>>window; curve>astronomy; cushion>carpet; cushion>chair; cushion>fashion; cushion>feather; cushion>furniture; cushion>grass; cushion>leather; cushion>palace; cushion>paper; cushion>pillow; cushion>soil; cushion>wood; custom>customs; custom>tradition; customer>consumer; customer>employee; customer>marketing; customer>seller; customs>authority; customs>export; customs>hazard; customs>port; customs>tax; cut>wound; cutlery>camping; cutlery>fast food; cutlery>food; cutlery>fork; cutlery>knife; cutlery>plastic; cutlery>razor; cutlery>spoon; cutlery>steel; cutlery>word; cutlery>tool; cv>syllable; cycle>bicycle; cycling>bicycle; cycling>carbon dioxide; cycling>city; cycling>obesity; cycling>recreation; cycling>sport; cycling>transport; cyclist>cycling; dad>father; damage>injury; dance>animal; dance>audience; dance>ballet; dance>ceremony; dance>civilization; dance>culture; dance>disco; dance>entertainment; dance>exercise; dance>gesture; dance>gymnastics; dance>hip-hop; dance>history; dance>individuality; dance>knowledge; dance>music; dance>narrative; dance>performance; dance>professional; dance>rainforest; dance>rhythm; dance>ritual; dance>scholar; dance>society; dance>symbol; dance>vocabulary; dancer>dance; dancing>dance; danger>risk; darkness>black; darkness>energy; darkness>shadow; dash>dialogue; dash>dictionnaire; dash>full stop; dash>hyphen; dash>prefix; dash>punctuation; data>alphabet; data>computer; data>database; data>engineering; data>geography; data>image; data>information; data>knowledge; data>measurement; data>number; data>sign; data>statistics; database>acid; database>availability; database>data; database>economy; database>email; database>knowledge; database>library; database>market; database>raid; database>security; database>spreadsheet; daughter>female; daughter>girl; daughter>offspring; daughter>parent; daughter>son; daughter>woman; dawn>horizon; dawn>morning; dawn>noon; dawn>pie; dawn>sky; dawn>sun; dawn>sunrise; dawn>sunset; day>astronomy; day>atom; day>calendar; day>daylight; day>deer; day>evening; day>holiday; day>horizon; day>hour; day>midnight; day>morning; day>night; day>noon; day>public transport; day>rabbit; day>season; day>second; day>star; day>sun; day>sunlight; day>sunrise; day>sunset; day>tide; day>time; day>water; day>week; day>year; daylight>earth; daylight>energy; daylight>moonlight; daylight>noon; daylight>pain; daylight>sun; daylight>sunlight; daylight>sunrise; daylight>sunset; daylight>window; deal>contract; death>accident; death>adaptation; death>animal; death>breath; death>bunial; death>cancer; death>coal; death>consciousness; death>disease; death>evolution; death>examination; death>exercise; death>extinction; death>funeral; death>gene; death>heart; death>human; death>inheritance; death>injury; death>life; death>longevity; death>medicine; death>murder; death>nerve; death>obesity; death>oxygen; death>philosophy; death>predator; death>scenario; death>science fiction; death>skeleton; death>stroke; death>suicide; death>time; death>tobacco; debate>argument; debate>audience; debate>controversy; debate>conversation; debate>election; debate>entertainment; debate>judge; debate>law; debate>majority; debate>parliament; debate>president; debate>prime minister; debate>proposition; debate>team; debate>vote; debit card>bank account; debit card>cash; debit card>cheque; debit card>credit card; debit card>euro; debit card>logo; debit card>plastic; debit card>retailer; debit card>signature; debit card>travel agent; debit card>asset; debit card>banking; debit card>company; debit card>corporation; debit card>credit card; debit card>currency; debit card>economist; debit card>finance; debit card>government; debit card>inflation; debit card>interest; debit card>investment; debit card>loan; debit card>metaphor; debit card>money; debit card>payment; debit card>property; debit card>risk; debit card>saving; debit card>stock; debit card>time; debit card>year; decade>century; decade>millennium; decade>year; december>day; december>length; december>month; december>year; deception>anger; deception>criticism; deception>embarrassment; deception>experiment; deception>forgery; deception>fraud; deception>ink; deception>lie; deception>propaganda; deception>psychology; deception>reality; deception>self-esteem; deception>sound; deception>truth; decision>judgment; deck>bus; deck>floor; deck>store; deck>swimming pool; decline>culture; decoration>beauty; dedication>chapel; dedication>icon; dedication>temple; deer>adjective; deer>animal; deer>caif; deer>cattle; deer>dna; deer>fruit; deer>leaf; deer>liver; deer>mammal; deer>predator; deer>salmon; deer>stomach; deer>turkey; defeat>failure; defeat>victory; deficiency>construction; definition>phrase; definition>prime minister; definition>rectangle; definition>symbol; definition>triangle; definition>word; degree>comparative; degree>superlative; delegation>leadership; delegation>management; delight>happiness; demand>glasses; demand>recession; demand>consensus; democracy>constitution; democracy>corporation; democracy>human rights; democracy>intelligence; democracy>law; democracy>organization; democracy>president; democracy>prime minister; democracy>referendum; democracy>republic; democracy>revolution; democracy>socialism; democracy>wealth; denial>attention; denial>bias; denial>death; denial>emotion; denial>evidence; denial>harassment; denial>lie; denial>rape; denial>reality; denial>research; denial>truth; denim>boot; denim>cotton; denim>documentary; denim>dress; denim>handbag; denim>hat; denim>jacket; denim>jeans; denim>shirt; denim>shoe; denim>shorts; density>air; density>aluminium; density>copper; density>diamond; density>earth; density>gold; density>gram; density>iron; density>kilogram; density>lead; density>liquid; density>pressure; density>silver; density>solution; density>sun; density>temperature; density>tin; density>water; density>weight; density>volume; density>wood; dentist>antibiotic; dentist>mouth; deodorant>alcohol; deodorant>aluminium; deodorant>bacteria; deodorant>dna; deodorant>inventor; deodorant>irritation; deodorant>perfume; department store>clock; department store>escalator; department store>marketing; department store>redevelopment; department store>retail; department>department store; department>essay; department>government; department>university; deprivation>liberty; deprivation>poverty; deprivation>starvation; descendant>ancestor; descendant>hierarchy; description> cliché; description>definition; description>fiction; description>imagination; description>narrative; description>relevance; description>sentiment; desert>ant; desert>camel; desert>carbon dioxide; desert>cattle; desert>continent; desert>copper; desert>drought; desert>earth; desert>explosive; desert>fly; desert>goat; desert>gold; desert>ice; desert>iron; desert>lake; desert>landscape; desert>mammal; desert>man; desert>region; desert>reptile; desert>salt; desert>science fiction; desert>sheep; desert>slave; desert>snake; desert>snow; desert>spider; desert>sun; desert>sunlight; desert>temperature; desert>turkey; design>analysis; design>architect; design>architecture; design>clothing; design>construction; design>creativity; design>definition; design>designer; design>document; design>emotion; design>engineering; design>evaluation; design>fashion; design>goal; design>implementation; design>management; design>manufacturing; design>pottery; design>presentation; design>requirement; design>research; design>science; design>specification; design>thought; design>architect; design>architecture; design>clothing; design>designer; design>design; design>engineering; design>furniture; design>painting; design>profession; design>sculpture; design>marketing; design>book; design>bookmark; design>computer; design>document; design>furniture; design>office; design>pen; design>steel; design>wood; design>writing; desktop>desk; desperation>panic; dessert>biscuit; dessert>cake; dessert>cookie; dessert>fat; dessert>flour; dessert>fruit; dessert>honey; dessert>ice cream; dessert>jam; dessert>pastry; dessert>pie; dessert>pudding; dessert>sugar; destination>travel; destiny>art; destiny>luck; destiny>philosophy; destiny>proposition; detail>complexity; detective>burglary; detective>civilian; detective>credit card; detective>crime; detective>fiction; detective>fraud; detective>inspector; detective>police; detective>robbery; determination>decision; determination>determiner; determination>measurement; determiner>adjective; determiner>grammar; determiner>noun; determiner>phrase; determiner>reference; determiner>word; device>gadget; device>machine; device>tool; devil>angel; devil>beauty; devil>culture; devil>evil; devil>goat; devil>god; devil>hell; devil>judge; devil>legend; devil>pig; devil>prosecutor; devil>religion; devil>sheep; devil>sin; devil>wisdom; diagnosis>experience; diagram>architect; diagram>arrow; diagram>chart; diagram>engineering; diagram>grammar; diagram>graphics; diagram>illustration; diagram>information; diagram>map; diagram>synonym; dialect>elite; dialect>jargon; dialect>language; dialect>slang; dialect>vocabulary; dialogue>conversation; dialogue>god; dialogue>language; dialogue>literature; dialogue>narrative; dialogue>philosophy; diamond>carbon; diamond>carbon dioxide; diamond>crystal; diamond>earth; diamond>electronics; diamond>ice; diamond>icon; diamond>laser; diamond>oxygen; diamond>toughness; diamond>>window; diamond>x-ray; diary>biography; diary>blog; diary>fiction; diary>witness; dice>board game; dice>density; dice>gambling; dice>horse; dice>museum; dice>plastic; dice>plural; dice>singular; dice>sphere; dictionary>computer; dictionary>concept; dictionary>definition; dictionary>idiom; dictionary>metaphor; difficulty>problem; digestion>acid; digestion>alcohol; digestion>animal; digestion>bacteria; digestion>beak; digestion>bird; digestion>blood; digestion>cat; digestion>cheese; digestion>cow; digestion>fat; digestion>food; digestion>liver; digestion>mammal; digestion>mouth; digestion>muscle; digestion>nerve; digestion>nutrition; digestion>pig; digestion>protein; digestion>silk; digestion>steel; digestion>stomach; digestion>sugar; digestion>tennis; digestion>tongue; digital camera>camera; digital camera>electronics; digital camera>mobile phone; digital camera>photograph; digital camera>photographer; digital camera>portrait; digital camera>video; dignity>abortion; dignity>angel; dignity>anger; dignity>conscience; dignity>god; dignity>human rights; dignity>integrity; dignity>pride; dignity>privacy; dignity>reason; dignity>self-esteem; dignity>self-respect; dignity>video game; dilemma>idiom; dilemma>logic; dilemma>paradox; dilemma>problem; dining room>castle; dining room>kitchen; dining room>living room; dining room>staircase; dinner>breakfast; dinner>dessert; dinner>food; dinner>lunch; dinner>meal; dinner>noon; dinner>snack; dinner>sunday; dinner>supper; dinosaur>advertising; dinosaur>biology; dinosaur>bird; dinosaur>bone; dinosaur>cheek; dinosaur>chemistry; dinosaur>chicken; dinosaur>computer; dinosaur>crocodile; dinosaur>extinction; dinosaur>feather; dinosaur>fiction; dinosaur>film; dinosaur>geology; dinosaur>kidney; dinosaur>literature; dinosaur>mammal; dinosaur>nest; dinosaur>physics; dinosaur>protein; dinosaur>reptile; dinosaur>science; dinosaur>skeleton; dinosaur>snake; dinosaur>tooth; dinosaur>wrist; diploma>ambassador; diploma>delegate; diploma>diplomacy; diploma>diplomat; diploma>electronics; diploma>king; diploma>leather; diploma>university; diplomacy>ambassador; diplomacy>climate change; diplomacy>culture; diplomacy>diplomat; diplomacy>economics; diplomacy>human rights; diplomacy>negotiation; diplomacy>politician; diplomacy>propaganda; diplomacy>republic; diplomacy>sailing; diplomacy>strategy; diplomacy>trade; diplomacy>treaty; diplomat>ambassador; diplomat>culture; diplomat>diploma; diplomat>diplomacy; diplomat>economics; diplomat>hip; diplomat>law; diplomat>self-esteem; diplomat>university; directions>direction; dirt>clothes; dirt>commerce; dirt>disgust; dirt>dust; dirt>dustbin; dirt>immune system; dirt>pregnancy; dirt>restaurant; dirt>skin; dirt>soil; disability>blindness; disability>disease; disability>employment; disability>extreme sports; disability>fitness; disability>safety; disability>sense; disability>software; disability>transportation; disability>wheelchair; disadvantage>extinction; disagreement>consensus; disagreement>controversy; disappointment>blame; disappointment>frustration; disappointment>grief; disappointment>happiness; disappointment>immune system; disappointment>lottery; disappointment>optimism; disappointment>probability; disappointment>risk; disappointment>stock market; disaster>accident; disaster>crisis; disaster>earthquake; disaster>emergency; disaster>explosion; disaster>fire; disaster>flood; disaster>hazard; disaster>jazz; disc jockey>microphone; disc jockey>nightclub; disc jockey>stadium; disc>disc jockey; discipline>motivation; discipline>prison; discipline>punishment; discipline>self-control; discipline>training; discipline>virtue; disco>album;

disco>arrangement; disco>baseball; disco>celebrity; disco>cello; disco>disc jockey; disco>dj; disco>flute; disco>hip-hop; disco>jazz; disco>medal; disco>music; disco>necklace; disco>nightclub; disco>orchestra; disco>piano; disco>racism; disco>soundtrack; disco>techno; disco>television; disco>trumpet; disco>violin; disco>comfort>comfort; discretion>appeal; discretion>judge; discretion>jury; discretion>noun; discretion>police; discretion>prosecutor; discretion>employer; discrimination>gender; discrimination>institution; discrimination>nationality; discrimination>prejudice; discrimination>racism; discrimination>slavery; discrimination>stereotype; discussion>conversation; disease>addiction; disease>attention; disease>biology; disease>cancer; disease>cure; disease>death; disease>disability; disease>emotion; disease>exercise; disease>illness; disease>infection; disease>injury; disease>medication; disease>metaphor; disease>nutrition; disease>obesity; disease>disability; disease>outbreak; disease>pain; disease>poverty; disease>pregnancy; disease>slavery; disease>stroke; disease>surgery; disease>symptom; disease>vaccination; disguise>celebrity; disguise>costume; disguise>glasses; disguise>mask; disguise>science fiction; disgust>anger; disgust>consciousness; disgust>consent; disgust>contempt; disgust>disgust; disgust>emotion; disgust>fear; disgust>god; disgust>milk; disgust>personality; disgust>privacy; disgust>racism; disgust>rat; disgust>sadness; disgust>sex; disgust>shame; dishonesty>consent; dishonesty>court; dishonesty>fraud; dishonesty>jury; dishonesty>robbery; dishonesty>theft; dishwasher>cutlery; dishwasher>perfume; dishwasher>restaurant; dishwasher>salt; dishwasher>temperature; dishwasher>washing machine; disk>disc; dislike>disgust; disorder>disease; disorder>belief; disposition>mind; disposition>truth; dispute>controversy; disrespect>respect; disruption>adoption; dissertation>thesis; distance>formula; distance>length; distance>physics; distance>ruler; distance>statistics; distinction>award; distraction>attention; distraction>prayer; distress>suffering; district>authority; district>county; district>leisure; district>recycling; district>region; district>tax; district>turkey; dive>diving; diver>diving; diving>dance; diving>gymnastics; diving>sport; diving>swimming pool; divorce>addiction; divorce>god; divorce>lawyer; divorce>magistrate; divorce>marriage; divorce>workaholic; divorce>vow; dna>agriculture; dna>animal; dna>atom; dna>bacteria; dna>biology; dna>blood; dna>brain; dna>cancer; dna>carbon; dna>earth; dna>evolution; dna>gene; dna>genetics; dna>hair; dna>life; dna>plant; dna>protein; dna>skin; dna>species; dna>temperature; dna>virus; dna>x-ray; doctor>surgeon; document>author; document>book; document>contract; document>evidence; document>information; document>ink; document>journal; document>laptop; document>material; document>paper; document>privacy; document>radio; document>report; document>sign; document>television; document>thesis; dog>animal; dog>blindness; dog>cat; dog>chocolate; dog>fox; dog>garlic; dog>grape; dog>horse; dog>human; dog>hunting; dog>leopard; dog>mammal; dog>pet; dog>pregnancy; dog>puppy; dog>restaurant; dog>tail; dog>tick; dog>tiger; dog>wolf; doll>archaeology; doll>art; doll>bone; doll>cereal; doll>cloth; doll>clothing; doll>fashion; doll>fur; doll>furniture; doll>leather; doll>plastic; doll>psychologist; doll>rubber; doll>slave; doll>toy; doll>transportation; doll>wood; dollar>currency; dollar>euro; dolphin>culture; dolphin>disease; dolphin>eyesight; dolphin>fish; dolphin>garlic; dolphin>infection; dolphin>navy; dolphin>review; dolphin>shark; dolphin>skeleton; dolphin>taste; dolphin>tuna; dolphin>whale; donation>blood; donation>cash; donation>clothing; donation>consideration; donation>food; donation>gift; donation>toy; donkey>animal; donkey>cartoon; donkey>desert; donkey>mammal; donkey>proverb; donkey>sheep; donkey>straw; donkey>synonym; donkey>zebra; donor>donation; doom>destiny; door>accident; door>air conditioning; door>alarm; door>animal; door>atmosphere; door>ceiling; door>chest; door>climate; door>convenience; door>curtain; door>disguise; door>fire; door>floor; door>garden; door>gate; door>glass; door>horse; door>id card; door>knee; door>ladder; door>light; door>literature; door>metaphor; door>noise; door>people; door>pressure; door>prison; door>privacy; door>remote control; door>ritual; door>rubber; door>safety; door>security; door>switch; door>ton; door>wardrobe; doorway>door; dose>quantity; doubt>authority; doubt>belief; doubt>childhood; doubt>deception; doubt>emotion; doubt>fact; doubt>future; doubt>history; doubt>law; doubt>logic; doubt>mind; doubt>paradox; doubt>politics; doubt>probability; doubt>question; doubt>reality; doubt>reason; doubt>religion; doubt>tradition; doubt>uncertainty; download>email; draft>doubt; drama>actor; drama>audience; drama>collaboration; drama>dance; drama>dialogue; drama>entertainment; drama>episode; drama>fiction; drama>film; drama>grammar; drama>institution; drama>literature; drama>music; drama>opera; drama>performance; drama>poetry; drama>radio; drama>ritual; drama>soap opera; drama>song; drama>television; drama>theatre; drama>tragedy; drama>wit; draught>draft; drawback>commerce; drawback>export; drawback>law; drawback>sugar; drawback>warehouse; drawer>drawing; drawing>blackboard; drawing>brush; drawing>diagram; drawing>illustration; drawing>ink; drawing>leather; drawing>paper; drawing>pen; drawing>pencil; drawing>ruler; drawing>shade; drawing>silver; dream>anger; dream>anxiety; dream>creativity; dream>evil; dream>earth; dream>fantasy; dream>fear; dream>happiness; dream>heaven; dream>idea; dream>illness; dream>image; dream>mind; dream>nightmare; dream>novelist; dream>perception; dream>prediction; dream>sadness; dream>scientist; dream>sleep; dream>taste; dress>bride; dress>clothing; dress>fashion; dress>girl; dress>skirt; dress>tennis; dress>thigh; dress>trousers; dress>wedding; dress>woman; drink>alcohol; drink>beer; drink>cancer; drink>carrot; drink>chemistry; drink>coffee; drink>cucumber; drink>culture; drink>food; drink>fruit; drink>human; drink>juice; drink>lemonade; drink>liquid; drink>milk; drink>pub; drink>soft drink; drink>soup; drink>spoon; drink>tea; drink>water; drink>wine; drink>yogurt; drive>motivation; drive>road; drop>chest; drop>waist; drought>agriculture; drought>average; drought>climate change; drought>desert; drought>disaster; drought>economy; drought>erosion; drought>famine; drought>habitat; drought>human; drought>hunger; drought>industry; drought>lake; drought>landscape; drought>rainforest; drought>refugee; drought>ship; drought>snake; drought>soil; drought>unrest; drought>war; drought>wind; drug>animal; drug>beer; drug>body; drug>chemical; drug>cigarette; drug>coffee; drug>consciousness; drug>cream; drug>culture; drug>food; drug>government; drug>human; drug>illness; drug>law; drug>matter; drug>medicine; drug>mind; drug>mouth; drug>perception; drug>pharmacist; drug>pharmacy; drug>tobacco; drug>wine; drum>jazz; drum>sound; duck>animal; duck>baseball; duck>beak; duck>bird; duck>fox; duck>swan; dump>waste; duration>time; dust>carpet; dust>climate change; dust>desert; dust>engineering; dust>fur; dust>hair; dust>laptop; dust>manufacturing; dust>material; dust>paper; dust>repair; dust>road; dust>surface; duty>debt; duty>employment; duty>obligation; duty>sacrifice; duty>soldier; duty>tradition; duvet>blanket; duvet>cotton; duvet>feather; duvet>pillow; duvet>silk; duvet>wool; dvd>cd; dvd>movie; dvd>pencil; eagerness>enthusiasm; eagle>beak; eagle>bird; eagle>extinction; eagle>religion; eagle>snake; eagle>sun; ear>bat; ear>cancer; ear>earring; ear>head; ear>muscle; ear>sense; ear>sound; earnings>commodity; earnings>corporation; earnings>income; earnings>investment; earnings>tax; earring>bacteria; earring>bone; earring>ear; earring>friction; earring>glass; earring>infection; earring>jewellery; earring>metal; earring>plastic; earring>sailor; earring>wood; earth>aluminium; earth>atmosphere; earth>carbon dioxide; earth>chemical; earth>climate; earth>culture; earth>density; earth>desert; earth>dinosaur; earth>earthquake; earth>evolution; earth>geography; earth>geology; earth>global warming; earth>human; earth>iron; earth>life; earth>lightning; earth>mammal; earth>metre; earth>oxygen; earth>ozone; earth>planet; earth>pollution; earth>satellite; earth>season; earth>species; earth>sun; earth>sunlight; earth>tide; earth>tornado; earth>volcano; earth>world; earthquake>building; earthquake>density; earthquake>disease; earthquake>earth; earthquake>fire; earthquake>liquid; earthquake>turkey; earthquake>volcano; east>adjective; east>adverb; east>earth; east>geography; east>map; east>north; east>noun; east>south; east>sun; east>west; echo>telephone; ecology>adaptation; ecology>agriculture; ecology>ant; ecology>bacteria; ecology>bee; ecology>biology; ecology>carbon; ecology>carbon dioxide; ecology>climate; ecology>consumer; ecology>coral; ecology>dolphin; ecology>energy; ecology>erosion; ecology>evolution; ecology>extinction; ecology>flower; ecology>gene; ecology>genetics; ecology>global warming; ecology>immigration; ecology>landscape; ecology>leaf; ecology>materialism; ecology>ocean; ecology>oxygen; ecology>pond; ecology>population; ecology>predator; ecology>science; ecology>species; ecology>temperature; ecology>wasp; ecology>whale; economics>banking; economics>budget; economics>capitalism; economics>choice; economics>communication; economics>corporation; economics>economy; economics>exchange rate; economics>experiment; economics>finance; economics>globalization; economics>historian; economics>inflation; economics>insurance; economics>leisure; economics>management; economics>market; economics>money; economics>monopoly; economics>nature; economics>paradigm; economics>policy; economics>politics; economics>pollution; economics>poverty; economics>price; economics>recession; economics>scarcity; economics>science; economics>slavery; economics>slope; economics>socialist; economics>statistics; economics>sustainability; economics>technology; economics>trade; economics>uncertainty; economics>unemployment; economics>wealth; economist>bank; economist>business; economist>college; economist>commerce; economist>communication; economist>economics; economist>finance; economist>globalization; economist>government; economist>history; economist>law; economist>management; economist>market; economist>marketing; economist>philosophy; economist>policy; economist>politician; economist>politics; economist>statistics; economist>theory; economist>university; economy>agriculture; economy>bank; economy>banking; economy>capitalism; economy>coal; economy>commerce; economy>company; economy>competition; economy>com; economy>currency; economy>debit; economy>debt; economy>demand; economy>economics; economy>economist; economy>engineering; economy>exchange rate; economy>film; economy>finance; economy>geography; economy>globalization; economy>history; economy>inflation; economy>infrastructure; economy>investment; economy>iron; economy>management; economy>manufacturing; economy>mining; economy>profession; economy>research; economy>scarcity; economy>stock market; economy>technology; economy>trade; economy>transport; economy>unemployment; economy>wood; economy>world; edge>blade; edition>paper; education>adult; education>agriculture; education>architecture; education>biology; education>child; education>college; education>curriculum; education>diploma; education>engineering; education>experience; education>history; education>knowledge; education>learning; education>literacy; education>medicine; education>organization; education>philosopher; education>philosophy; education>politics; education>profession; education>professor; education>psychology; education>school; education>science; education>secondary school; education>student; education>syllabus; education>teacher; education>telephone; education>training; education>university; education>violin; education>writing; effect>result; effectiveness>efficiency; effectiveness>management; effectiveness>medicine; effectiveness>physics; efficiency>effectiveness; effort>energy; election>business; election>corporation; election>propaganda; election>referendum; election>statistics; electrician>electronics; electrician>hammer; electricity>air conditioning; electricity>atom; electricity>earth; electricity>electronics; electricity>force; electricity>friction; electricity>headache; electricity>height; electricity>lighting; electricity>lightning; electricity>matter; electricity>muscle; electricity>shark; electricity>steam; electricity>sugar; electricity>switch; electricity>torture; electricity>touch; electricity>wave; electronics>computer; electronics>counter; electronics>electricity; electronics>engineering; electronics>heat; electronics>radiation; electronics>radio; electronics>spice; electronics>switch; electronics>system; electronics>telecommunications; electronics>wire; elegance>beauty; elegance>chemistry; elegance>design; elegance>effectiveness; elegance>engineering; elegance>essence; elegance>pharmacy; elegance>simplicity; elegance>synonym; element>weather; elephant>animal; elephant>camel; elephant>circus; elephant>desert; elephant>dna; elephant>dolphin; elephant>emotion; elephant>empathy; elephant>erosion; elephant>giraffe; elephant>lion; elephant>self-awareness; elephant>skull; elephant>tiger; elephant>zoo; elite>capitalism; elite>tax; email>bracket; email>corporation; email>laptop; email>message board; email>mobile phone; email>spelling; embarrassment>anger; embarrassment>anxiety; embarrassment>birthday; embarrassment>criticism; embarrassment>denial; embarrassment>dignity; embarrassment>emotion; embarrassment>environment; embarrassment>gossip; embarrassment>knowledge; embarrassment>privacy; embarrassment>shame; embarrassment>skill; embrace>acceptance; embrace>hug; emergency>accident; emergency>ambulance; emergency>donation; emergency>electricity; emergency>fire; emergency>firefighter; emergency>flood; emergency>gas; emergency>government; emergency>hazard; emergency>health; emergency>human; emergency>life; emergency>likelihood; emergency>management; emergency>observation; emergency>police; emergency>principle; emergency>probability; emergency>professional; emergency>property; emergency>rescue; emergency>risk; emergency>stroke; emergency>tax; emergency>tornado; emergency>training; emission>noise; emotion>aggression; emotion>anger; emotion>artificial intelligence; emotion>contempt; emotion>curiosity; emotion>disgust; emotion>disposition; emotion>economics; emotion>education; emotion>evolution; emotion>fear; emotion>feeling; emotion>happiness; emotion>history; emotion>hunger; emotion>irritation; emotion>law; emotion>literature; emotion>love; emotion>mammal; emotion>marriage; emotion>medicine; emotion>motivation; emotion>philosophy; emotion>psychology; emotion>reason; emotion>reptile; emotion>sadness; emotion>virtue; empathy>crowd; empathy>dolphin; empathy>emotion; empathy>fantasy; empathy>pity; empathy>science fiction; empathy>sympathy; empathy>toddler; emperor>coup; emperor>empire; emperor>flag; emperor>prime minister; emperor>prince; emperor>religion; emperor>republic; empire>commerce; empire>election; empire>emperor; empire>euro; empire>realm; empire>republic; empire>trade; employment>agriculture; employment>contract; employment>debate; employment>democracy; employment>discrimination; employment>employee; employment>employer; employment>globalization; employment>human rights; employment>manufacturing; employment>poverty; employment>sign; employment>slavery; employment>unemployment; employment>wage; employment>volunteer; employment>workforce; ending>end; endurance>anxiety; endurance>patience; endurance>resilience; enemy>anger; enemy>battle; enemy>devil; enemy>disease; enemy>envy; enemy>evil; enemy>fear; enemy>friend; enemy>friendship; enemy>frustration; enemy>god; enemy>hate; enemy>hated; enemy>jealousy; enemy>literature; enemy>pact; enemy>propaganda; enemy>protagonist; enemy>religion; enemy>respect; enemy>war; enemy>violence; energy>atmosphere; energy>carbon dioxide; energy>crystal; energy>earthquake; energy>ecology; energy>force; energy>friction; energy>fuel; energy>hail; energy>heat; energy>light; energy>lightning; energy>machine; energy>matter; energy>momentum; energy>mountain; energy>oxygen; energy>potential; energy>pressure; energy>protein; energy>rain; energy>snow; energy>space; energy>speed; energy>star; energy>system; energy>temperature; energy>thermometer; energy>time; energy>tornado; energy>water; energy>wind; energy>volcano; engine>carbon dioxide; engine>carbon footprint; engine>carbon monoxide; engine>cattle; engine>electricity; engine>energy; engine>fluid; engine>force; engine>fuel; engine>gear; engine>global warming; engine>hard drive; engine>heat; engine>horse; engine>liquid; engine>machine; engine>mining; engine>muscle; engine>oxygen; engine>pressure; engine>pump; engine>rocket; engine>rope; engine>ship; engine>steam; engine>steel; engine>temperature; engine>wind; engineer>accountant; engineer>architect; engineer>business; engineer>education; engineer>engineering; engineer>industry; engineer>lawyer; engineer>management; engineer>pharmacist; engineer>politician; engineer>profession; engineer>science fiction; engineer>scientist; engineer>turkey;

engineering>aircraft; engineering>architecture; engineering>artificial intelligence; engineering>biology; engineering>bridge; engineering>canal; engineering>chemistry; engineering>column; engineering>compromise; engineering>computer; engineering>design; engineering>economics; engineering>electricity; engineering>electronics; engineering>energy; engineering>engineer; engineering>harbour; engineering>infrastructure; engineering>logic; engineering>medicine; engineering>philosophy; engineering>physics; engineering>profession; engineering>robot; engineering>science; engineering>simulation; engineering>technology; engineering>telecommunications; engineering>transportation; enjoyment>happiness; enquiry>inquiry; enterprise>business; enterprise>company; enterprise>organization; entertainer>entertainment; entertainment>animation; entertainment>artificial intelligence; entertainment>audience; entertainment>ball; entertainment>ballet; entertainment>baseball; entertainment>basketball; entertainment>birthday; entertainment>board game; entertainment>camping; entertainment>cartoon; entertainment>ceremony; entertainment>chef; entertainment>chess; entertainment>choir; entertainment>circus; entertainment>clown; entertainment>comedian; entertainment>comedy; entertainment>composer; entertainment>concert; entertainment>cooking; entertainment>cricket; entertainment>dance; entertainment>drama; entertainment>education; entertainment>employment; entertainment>fair; entertainment>fantasy; entertainment>festival; entertainment>film; entertainment>fun; entertainment>gambling; entertainment>game; entertainment>ice hockey; entertainment>imagination; entertainment>insight; entertainment>insult; entertainment>irony; entertainment>jazz; entertainment>joke; entertainment>leisure; entertainment>literature; entertainment>marketing; entertainment>millennium; entertainment>monkey; entertainment>music; entertainment>musician; entertainment>novel; entertainment>opera; entertainment>orchestra; entertainment>parade; entertainment>party; entertainment>performance; entertainment>poetry; entertainment>professional; entertainment>public transport; entertainment>radio; entertainment>recreation; entertainment>rhythm; entertainment>running; entertainment>singing; entertainment>sport; entertainment>stadium; entertainment>television; entertainment>theatre; entertainment>tourist; entertainment>tournament; entertainment>warrior; entertainment>wedding; entertainment>video game; entertainment>wit; entertainment>writer; entertainment>zoo; enthusiasm>emotion; enthusiasm>enjoyment; enthusiasm>motivation; enthusiasm>poet; enthusiasm>prayer; entity>ghost; entity>life; entity>matter; entity>spirit; entrance>door; entrance>gate; envelope>government; envelope>mail; envelope>propaganda; envelope>steam; environment>ecology; environmentalist>sustainability; envy>aggression; envy>anger; envy>competition; envy>faith; envy>green; envy>happiness; envy>jealousy; envy>love; envy>miracle; envy>motivation; envy>priest; envy>resentment; envy>self-esteem; envy>sin; envy>wealth; envy>well-being; envy>virtue; envy>wisdom; episode>drama; episode>edition; episode>news; episode>novel; episode>novel; episode>soap opera; equation>addition; equation>formula; equipment>tool; era>music; era>time; erosion>agriculture; erosion>climate change; erosion>drought; erosion>forest; erosion>river; erosion>sky; erosion>soil; erosion>starvation; erosion>stream; erosion>vegetation; error>appeal; error>biology; error>child; error>coin; error>crime; error>design; error>dna; error>engineer; error>evolution; error>gadgets; error>government; error>grammar; error>illusion; error>information; error>jury; error>language; error>machine; error>medal; error>noise; error>offspring; error>parent; error>performance; error>pronunciation; error>punctuation; error>runway; error>sin; error>statistics; error>system; error>uncertainty; escalator>airport; escalator>aluminium; escalator>department store; escalator>hotel; escalator>pedestrian; escalator>stadium; escalator>verb; essay>analysis; essay>argument; essay>art; essay>criticism; essay>dissertation; essay>economics; essay>education; essay>metaphor; essay>music; essay>narrative; essay>novel; essay>philosophy; essay>poetry; essay>university; essay>writing; essence>materialism; essence>philosophy; essence>soul; euro>coin; euro>commodity; euro>credit card; euro>debit card; euro>exchange rate; euro>interest; euro>speculation; euro>target; evaluation>bias; evaluation>collaboration; evaluation>consumer; evaluation>controversy; evaluation>credibility; evaluation>customer; evaluation>data; evaluation>dignity; evaluation>education; evaluation>elite; evaluation>experiment; evaluation>goal; evaluation>government; evaluation>health care; evaluation>honesty; evaluation>individual; evaluation>information; evaluation>inquiry; evaluation>insight; evaluation>integrity; evaluation>interest; evaluation>interview; evaluation>knowledge; evaluation>management; evaluation>philosophy; evaluation>policy; evaluation>politics; evaluation>principle; evaluation>privacy; evaluation>questionnaire; evaluation>reality; evaluation>respect; evaluation>security; evaluation>self-esteem; evaluation>statistics; evening>afternoon; evening>dinner; evening>night; evening>sunset; event>business; event>ceremony; event>competition; event>festival; event>news; event>party; event>phenomenon; event>sport; evidence>argument; evidence>arrest; evidence>belief; evidence>bias; evidence>crime; evidence>debate; evidence>experiment; evidence>hypothesis; evidence>knowledge; evidence>laboratory; evidence>law; evidence>observation; evidence>philosophy; evidence>prosecutor; evidence>reason; evidence>resolution; evidence>truth; evidence>validity; evil>criticism; evil>devil; evil>ignorance; evil>murder; evil>neglect; evil>philosophy; evil>rape; evil>selfishness; evil>sin; evil>slavery; evil>terrorism; evolution>adaptation; evolution>ant; evolution>antibiotic; evolution>atmosphere; evolution>bacteria; evolution>bat; evolution>bee; evolution>biology; evolution>bird; evolution>chicken; evolution>crocodile; evolution>dinosaur; evolution>dna; evolution>donkey; evolution>earth; evolution>ecology; evolution>experiment; evolution>extinction; evolution>eye; evolution>fact; evolution>gene; evolution>generation; evolution>global warming; evolution>habitat; evolution>horse; evolution>immune system; evolution>insect; evolution>leg; evolution>life; evolution>mammal; evolution>materialism; evolution>monkey; evolution>mouse; evolution>offspring; evolution>oxygen; evolution>philosopher; evolution>plant; evolution>poet; evolution>population; evolution>protein; evolution>religion; evolution>reptile; evolution>sex; evolution>virus; exaggeration>actor; exaggeration>comedy; exaggeration>evil; exaggeration>gesture; exaggeration>portrait; exaggeration>praise; exaggeration>self-esteem; exaggeration>threat; exchange rate>bank; exchange rate>currency; exchange rate>finance; exchange rate>inflation; exchange rate>productivity; exchange>conversation; exchange>trade; exclamation mark>astrophysics; exclamation mark>full stop; exclamation mark>irony; exclamation mark>punctuation; exclamation mark>question mark; exclamation mark>triangle; exhaust>exhaustion; exhibit>exhibition; exhibit>museum; exhibition>archaeology; exhibition>architect; exhibition>chart; exhibition>craft; exhibition>drawing; exhibition>history; exhibition>map; exhibition>museum; exhibition>painting; exhibition>performance; exhibition>science; exhibition>sculpture; exhibition>technology; exhibition>writer; exile>coup; exile>prosecution; exile>punishment; exile>refugee; exile>solitude; existence>awareness; existence>belief; existence>consciousness; existence>death; existence>definition; existence>entity; existence>essence; existence>hierarchy; existence>life; existence>materialism; existence>matter; existence>mind; existence>persistence; existence>proposition; existence>reality; existence>sense; existence>world; exit>door; expedition>exploration; expenditure>cost; expense>asset; expense>controversy; expense>cost; expense>debit; expense>employee; expense>expenses; expense>money; expense>tuition; expenses>expense; experience>authority; experience>body; experience>consciousness; experience>customs; experience>data; experience>emotion; experience>empathy; experience>experiment; experience>expert; experience>extreme sports; experience>imagination; experience>individual; experience>intellect; experience>interaction; experience>logic; experience>memory; experience>mind; experience>perception; experience>philosophy; experience>prayer; experience>reality; experience>reason; experience>rumour; experience>sense; experience>thought; experience>time; experience>tourism; experience>virtual reality; experience>wisdom; experience>yoga; experiment>agriculture; experiment>astronomy; experiment>chemistry; experiment>ecology; experiment>economics; experiment>engineering; experiment>geology; experiment>hypothesis; experiment>laboratory; experiment>measurement; experiment>number; experiment>philosophy; experiment>protein; experiment>psychology; experiment>science; experiment>scientist; experiment>solution; experiment>statistics; experiment>system; expert>authority; expert>consultant; expert>education; expert>experience; expert>intellectual; expert>judgment; expert>knowledge; expert>law; expert>official; expert>opinion; expert>problem; expert>profession; expert>publication; expert>scholar; expert>skill; expert>technician; expert>training; expert>wisdom; explanation>belief; explanation>description; explanation>exploration; explanation>inquiry; explanation>knowledge; explanation>proposition; explanation>theory; explanation>understanding; explanation>adventure; explanation>explanation; explanation>history; explanation>information; explosion>animal; explosion>bomb; explosion>camera; explosion>chemical; explosion>energy; explosion>flame; explosion>gas; explosion>heat; explosion>missile; explosion>planet; explosion>pressure; explosion>star; explosion>sun; explosion>volcano; explosion>volume; export>customer; export>import; export>management; export>regulation; exposure>chemical; exposure>publicity; extinction>animal; extinction>biology; extinction>climate change; extinction>death; extinction>dinosaur; extinction>earth; extinction>ecology; extinction>evolution; extinction>global warming; extinction>goat; extinction>government; extinction>habitat; extinction>horse; extinction>mosquito; extinction>philosophy; extinction>plant; extinction>pollution; extinction>population; extinction>predator; extinction>rat; extinction>reproduction; extinction>risk; extinction>selection; extinction>species; extinction>technology; extinction>water; extinction>virus; extinction>zebra; extinction>zoo; extract>alcohol; extract>banana; extract>cherry; extract>grain; extract>lemon; extract>peach; extract>pineapple; extract>rose; extract>strawberry; extract>water; eye>snake; eye>brain; eye>camera; eye>color; eye>crystal; eye>darkness; eye>eyelid; eye>fish; eye>horse; eye>light; eye>mirror; eye>prawn; eye>pupil; eye>rabbit; eye>snail; eye>sunlight; eyebrow>anger; eyebrow>mammal; eyebrow>rain; eyebrow>sweat; eyelash>camel; eyelash>cow; eyelash>dust; eyelash>eyelid; eyelash>horse; eyelash>insect; eyelash>mammal; eyelash>mouse; eyelid>antibiotic; eyelid>bacteria; eyelid>death; eyelid>eyelash; eyelid>skin; face>brain; face>cheek; face>chin; face>communication; face>ear; face>emotion; face>eyebrow; face>eyelash; face>eyelid; face>forehead; face>hair; face>head; face>lip; face>nostril; face>person; face>sense; face>taste; face>temperature; face>tooth; facilities>facility; facility>building; facility>hotel; facility>installation; facility>resort; facility>school; fact>adverb; fact>crime; fact>experience; fact>hypothesis; fact>lie; fact>philosophy; fact>preposition; fact>reality; fact>theory; fact>truth; factory>canal; factory>cotton; factory>globalization; factory>independence; factory>industrialization; factory>interaction; factory>machine; factory>management; factory>manufacturing; factory>organization; factory>paint; factory>public transport; factory>regulation; factory>statistics; factory>tool; factory>tram; factory>warehouse; factory>wheel; failure>competition; failure>disaster; failure>observation; failure>perception; failure>prediction; fail>entertainment; fair>exhibition; fair>festival; fair>harvest; fair>holiday; fair>market; fair>people; fairness>justice; faith>belief; faith>confidence; faith>god; faith>knowledge; faith>logic; faith>mind; faith>perception; faith>philosopher; faith>philosophy; faith>probability; faith>psychologist; faith>reason; faith>religion; faith>virtue; fake>deception; fake>forgery; fall>autumn; fame>celebrity; family>advertising; family>animal; family>aunt; family>belief; family>brother-in-law; family>capitalism; family>city; family>civilization; family>community; family>cousin; family>daughter; family>divorce; family>father; family>grandmother; family>grandparent; family>household; family>human; family>industrialization; family>infant; family>love; family>marriage; family>mother; family>nation; family>nephew; family>niece; family>people; family>region; family>resource; family>science; family>sibling; family>sister-in-law; family>son; family>uncle; family>village; famine>agriculture; famine>bureaucracy; famine>cash; famine>climate; famine>climate change; famine>crime; famine>death; famine>disaster; famine>drought; famine>erosion; famine>farmer; famine>fishing; famine>food; famine>god; famine>grain; famine>hunger; famine>hunting; famine>income; famine>infrastructure; famine>law; famine>leisure; famine>market; famine>mobile phone; famine>money; famine>peasant; famine>relief; famine>seed; famine>starvation; famine>sustainability; famine>tax; famine>war; famine>vegetarian; famine>wheat; famine>volcano; fantasy>fiction; fantasy>hero; fantasy>history; fantasy>legend; fantasy>literature; fantasy>monster; fantasy>realm; fantasy>science fiction; fare>airline; fare>bus; fare>fee; fare>passenger; fare>public transport; farm>agriculture; farm>beef; farm>butter; farm>cattle; farm>cheese; farm>chicken; farm>coffee; farm>cotton; farm>cream; farm>democracy; farm>duck; farm>farmer; farm>farming; farm>fibre; farm>food; farm>fuel; farm>grain; farm>lake; farm>mammal; farm>meat; farm>milk; farm>produce; farm>river; farm>sea; farm>socialist; farm>stable; farm>tobacco; farm>tractor; farmer>agriculture; farmer>cattle; farmer>chicken; farmer>dog; farmer>duck; farmer>employment; farmer>farm; farmer>feather; farmer>gardener; farmer>gardening; farmer>goat; farmer>horse; farmer>market; farmer>meat; farmer>peasant; farmer>poverty; farmer>sheep; farmer>subsidy; farming>agriculture; fashion>beauty; fashion>brand; fashion>clothing; fashion>generation; fashion>geography; fashion>grammar; fashion>language; fashion>logo; fashion>peasant; fashion>perfume; fashion>profession; fashion>society; fashion>turkey; fast food>chicken; fast food>coast; fast food>cucumber; fast food>curry; fast food>cutlery; fast food>ice cream; fast food>junk food; fast food>meat; fast food>menu; fast food>onion; fast food>pancake; fast food>pizza; fast food>restaurant; fast food>rice; fast food>salad; fast food>sausage; fast food>soft drink; fast food>turkey; fat>butter; fat>chemistry; fat>energy; fat>gram; fat>hair; fat>liquid; fat>mouse; fat>obesity; fat>skin; fat>vitamin; fate>destiny; father>adjective; father>advertisement; father>bear; father>bird; father>cartoon; father>child; father>dog; father>dolphin; father>duck; father>fish; father>horse; father>housewife; father>human; father>insect; father>lion; father>marriage; father>mother; father>nest; father>parent; father>rape; father>reptile; father>swan; father>verb; father>wolf; father>error; favourite>architect; favourite>chess; favourite>essay; favourite>mushroom; favourite>prime minister; fear>adaptation; fear>anger; fear>anxiety; fear>bridge; fear>clown; fear>dancing; fear>death; fear>drum; fear>emotion; fear>evil; fear>evolution; fear>failure; fear>fright; fear>future; fear>ghost; fear>happiness; fear>mammal; fear>nightmare; fear>pain; fear>panic; fear>people; fear>psychologist; fear>risk; fear>sadness; fear>singing; fear>snake; fear>solitude; fear>spider; fear>terrorism; fear>threat; fear>tunnel; fear>uncertainty; fear>war; fear>water; feasts>festival; feather>beak; feather>bird; feather>blanket; feather>clothing; feather>dinosaur; feather>eagle; feather>eyelash; feather>hair; feather>heat; feather>mammal; feather>parrot; feather>penguin; feather>pillow; feather>pollution; feather>predator; feather>protein; feather>reptile; feather>skin; february>august; february>cabbage; february>day; february>monday; february>month; february>season; february>week; february>year; fee>apartment; fee>cost; fee>flight; fee>illness; fee>interest; fee>lottery; fee>luggage; fee>noise; fee>parking; fee>price; fee>refund; fee>shopping; fee>subsidy; fee>tourism; fee>tuition; fee>upgrade; feedback>electronics; feedback>gain; feedback>gene; feedback>information; feedback>interaction; feedback>investment; feedback>knowledge; feedback>organization; feedback>phenomenon; feedback>poetry; feedback>psychology; feedback>revolution; feedback>stock; feedback>stock market; feedback>system; feeling>emotion; feeling>experience; feeling>perception; feeling>touch; female>animal; female>ant; female>bee; female>bird; female>bust; female>breast; female>evolution; female>genetics; female>girl; female>human; female>insect; female>male; female>mammal; female>milk; female>plant; female>reproduction; female>sex; female>shark; female>woman; female>balcony; female>balcony; female>bridge; female>habitat; female>hedge; female>horse; female>transport; female>wall; female>water; ferry>boat; ferry>bridge; ferry>global warming; ferry>knot; ferry>ship; ferry>steam; ferry>tunnel; ferry>yacht; festival>fair; festival>god; festival>holiday;

festival>idiom; festival>meal; festival>party; festival>religion; festival>season; fever>aspirin; fever>camel; fever>cancer; fever>cold; fever>disease; fever>ear; fever>horse; fever>human; fever>surgery; fever>symptom; fiction>advertising; fiction>author; fiction>biography; fiction>blog; fiction>confusion; fiction>dialogue; fiction>fantasy; fiction>fear; fiction>film; fiction>history; fiction>imagination; fiction>literature; fiction>metaphor; fiction>narrative; fiction>novel; fiction>poetry; fiction>propaganda; fiction>property; fiction>protagonist; fiction>religion; fiction>school; fiction>science fiction; fiction>song; fiction>symbol; fiction>theatre; fiction>theory; fiction>tragedy; field>lawn; fight>combat; fighting>combat; figure>drawing; figure>number; figure>shape; film>actor; film>advertising; film>amateur; film>animation; film>art; film>ballet; film>camera; film>celebrity; film>cheese; film>commerce; film>culture; film>dialogue; film>download; film>dvd; film>entertainment; film>language; film>magazine; film>newspaper; film>opera; film>orchestra; film>photography; film>piano; film>sound; film>soundtrack; film>subtitles; film>technology; film>television; film>translation; film>video; finance>asset; finance>bank; finance>business; finance>certainty; finance>economics; finance>inflation; finance>insurance; finance>investment; finance>price; finance>retirement; finance>stock; finger>hand; finger>human; finger>injury; finger>joint; finger>muscle; finger>thumb; finger>toe; fire station>radio; fire>agriculture; fire>atom; fire>candle; fire>chemical; fire>cigarette; fire>coal; fire>cooking; fire>crime; fire>digestion; fire>electricity; fire>firefighter; fire>flame; fire>fuel; fire>habitat; fire>heat; fire>industry; fire>landscape; fire>lead; fire>light; fire>material; fire>oil; fire>school; fire>smoke; fire>temperature; fire>torture; fire>water; fire>vehicle; fire>wood; firefighter>carbon; firefighter>carbon monoxide; firefighter>fuel; firefighter>hazard; firefighter>horse; firefighter>nurse; firefighter>oxygen; firefighter>rescue; fireplace>architecture; fireplace>carbon monoxide; fireplace>chimney; fireplace>lung; fireplace>wood; firm>business; first language>language; fish>adaptation; fish>animal; fish>bee; fish>carbon dioxide; fish>digestion; fish>fishing; fish>heart; fish>jaw; fish>kidney; fish>liver; fish>mammal; fish>mouth; fish>nostril; fish>oxygen; fish>pain; fish>salmon; fish>shark; fish>skate; fish>species; fish>stomach; fish>suffering; fish>synonym; fish>tuna; fish>vein; fisherman>community; fisherman>culture; fisherman>fish; fisherman>fishing; fisherman>flood; fisherman>shark; fisherman>tuna; fishing>arrow; fishing>beer; fishing>boat; fishing>cod; fishing>community; fishing>crab; fishing>culture; fishing>demand; fishing>ecology; fishing>fish; fishing>fisherman; fishing>market; fishing>miracle; fishing>mouth; fishing>pleasure; fishing>protein; fishing>recreation; fishing>river; fishing>salmon; fishing>sea; fishing>shark; fishing>ship; fishing>tomb; fishing>tuna; fishing>water; fishing>wine; fish>squad; flag>advertising; flag>cargo; flag>communication; flag>country; flag>customs; flag>golf; flag>nation; flag>navy; flag>pollution; flag>referee; flag>shark; flag>socialism; flag>sport; flag>turkey; flag>wave; flag>yacht; flame>air; flame>atmosphere; flame>candle; flame>carbon; flame>carbon monoxide; flame>earth; flame>energy; flame>fire; flame>firework; flame>fuel; flame>gas; flame>heat; flame>industry; flame>laboratory; flame>light; flame>lighter; flame>oxygen; flame>ozone; flame>smoke; flame>temperature; flame>wood; flash>lightning; flat>apartment; flesh>animal; flesh>bullet; flesh>bony; flesh>fat; flesh>food; flesh>human; flesh>meat; flesh>muscle; flight>air; flight>aircraft; flight>atmosphere; flight>ball; flight>balloon; flight>bat; flight>bird; flight>bullet; flight>density; flight>dinosaur; flight>earth; flight>evolution; flight>firework; flight>force; flight>friction; flight>helicopter; flight>insect; flight>kite; flight>landing; flight>machine; flight>mammal; flight>missile; flight>momentum; flight>penguin; flight>rocket; flight>satellite; flight>ship; flight>skin; flight>species; flight>weight; flight>wing; flood>canal; flood>civilization; flood>commerce; flood>concrete; flood>culture; flood>death; flood>earthquake; flood>farmer; flood>lake; flood>property; flood>river; flood>thunderstorm; flood>tide; flood>water; flood>wind; floor>air conditioning; floor>balcony; floor>carpet; floor>ceiling; floor>employment; floor>soil; floor>storey; flour>bread; flour>cake; flour>carbon dioxide; flour>cereal; flour>coconut; flour>dessert; flour>explosive; flour>flower; flour>grain; flour>ingredient; flour>pancake; flour>pasta; flour>potato; flour>pudding; flour>rice; flour>root; flour>salt; flour>sauce; flour>sausage; flour>vitamin; flour>adaptation; flower>bee; flower>beer; flower>bird; flower>broccoli; flower>chicken; flower>dna; flower>extinction; flower>female; flower>fruit; flower>funeral; flower>garden; flower>honey; flower>insect; flower>leaf; flower>protein; flower>reproduction; flower>root; flower>rose; flower>seed; flower>spice; flower>symbol; flower>sympathy; flower>temperature; flower>temple; fluency>code; fluency>information; fluency>person; fluency>system; fluency>understanding; fluency>writing; fluid>gas; fluid>liquid; fluid>matter; fluid>physics; fluid>pressure; flute>human; flute>musician; flute>sound; flute>swan; flute>whistle; flute>volume; fly>butterfly; fly>dna; fly>fish; fly>insect; fly>literature; fly>mosquito; fly>novel; fly>poem; fly>species; fly>wound; fog>crystal; fog>hail; fog>ice; fog>mist; fog>slope; fog>steam; fog>valley; fog>water; folk>crowd; folk>ecology; folk>people; folk>tribe; follower>poem; food>acid; food>advertising; food>agriculture; food>animal; food>bacon; food>bacteria; food>bean; food>bee; food>beef; food>blood; food>brand; food>bread; food>broccoli; food>butcher; food>butter; food>cabbage; food>café; food>carrot; food>cereal; food>cheese; food>chef; food>chewing gum; food>chicken; food>chocolate; food>climate change; food>commodity; food>cooking; food>corporation; food>counter; food>ecology; food>energy; food>evolution; food>famine; food>fast food; food>fat; food>fish; food>fruit; food>frying pan; food>fuel; food>honey; food>human; food>hygiene; food>immune system; food>import; food>junk food; food>kidney; food>kitchen; food>lemon; food>lettuce; food>meal; food>meat; food>milk; food>muscle; food>mushroom; food>obesity; food>onion; food>oven; food>pasta; food>pea; food>peanut; food>plant; food>pork; food>potato; food>pottery; food>protein; food>rash; food>restaurant; food>rice; food>salad; food>salmon; food>salt; food>seed; food>soup; food>spinach; food>starvation; food>steam; food>sugar; food>supermarket; food>sustainability; food>sweet; food>taste; food>tobacco; food>tomato; food>toot; food>toot; food>toot; food>tuna; food>vegetable; food>vegetarian; food>wheat; food>vinegar; food>virus; food>vitamin; food>yogurt; food>clown; food>ankle; food>bone; food>cow; food>heel; food>hip; food>horse; food>infection; food>knee; food>leg; food>muscle; food>paw; food>sheep; food>shoe; food>sweat; football>basketball; football>blindness; football>gymnastics; football>ice hockey; football>leather; football>peasant; football>professional; football>referee; football>sand; football>silk; football>team; football>tradition; football>try; football>volleyball; football>yard; force>angle; force>atom; force>basketball; force>blog; force>day; force>density; force>diagram; force>earth; force>energy; force>flight; force>fluid; force>friction; force>heat; force>interaction; force>logic; force>measurement; force>momentum; force>nature; force>observation; force>physics; force>planet; force>potential; force>pressure; force>revolution; force>second; force>space; force>speed; force>surface; force>temperature; force>wave; force>wind; force>year; forehead>eyebrow; forehead>frown; forehead>wrinkle; forest>bacteria; forest>earth; forest>plant; forest>rainforest; forest>soil; forest>tree; forest>wilderness; forest>woodland; forger>currency; forger>deception; forger>document; forger>fraud; forger>label; forger>money; forger>photography; forgiveness>anger; forgiveness>god; forgiveness>grief; forgiveness>happiness; forgiveness>medicine; forgiveness>murder; forgiveness>punishment; forgiveness>religion; forgiveness>resentment; fork>bronze; fork>cutlery; fork>knife; fork>spoon; form>shape; formula>atom; formula>calculation; formula>computer; formula>equation; formula>ozone; formula>science; formula>sphere; formula>spreadsheet; formula>water; formula>volume; fortnight>day; fortnight>week; fortune>luck; fortune>wealth; fountain>paradise; fountain>pump; fox>animal; fox>berry; fox>bird; fox>dog; fox>extinction; fox>farm; fox>fish; fox>fruit; fox>fur; fox>grass; fox>insect; fox>mammal; fox>reptile; fox>snake; fox>species; fox>tail; frame>glasses; fraud>contract; fraud>credit card; fraud>crime; fraud>deception; fraud>money; fraud>stock market; freedom>liberty; frenzy>dvd; frenzy>murder; frenzy>narrative; frenzy>prison; friction>atmosphere; friction>carbon monoxide; friction>copper; friction>experiment; friction>explosion; friction>fluid; friction>force; friction>heat; friction>measurement; friction>road; friction>surface; friction>temperature; friday>corporation; friday>fish; friday>mosque; friday>potato; friday>saturday; friday>sunset; friday>thursday; friend>friendship; friendship>affection; friendship>bird; friendship>cancer; friendship>cat; friendship>castle; friendship>competition; friendship>discrimination; friendship>divorce; friendship>dog; friendship>empathy; friendship>farmer; friendship>happiness; friendship>honesty; friendship>hospital; friendship>infection; friendship>loyalty; friendship>mail; friendship>mammal; friendship>marriage; friendship>milk; friendship>nickname; friendship>philosophy; friendship>scarcity; friendship>self-esteem; friendship>sympathy; friendship>toy; friendship>understanding; friendship>vaccine; friend>fear; frog>beak; frog>bone; frog>carbon dioxide; frog>climbing; frog>electricity; frog>extinction; frog>eye; frog>fish; frog>heart; frog>kidney; frog>leg; frog>mammal; frog>mouth; frog>oxygen; frog>protein; frog>rib; frog>running; frog>snake; frog>tail; frog>tongue; frog>walking; frog>witch; frontier>border; frontier>turkey; frost>air; frost>crystal; frost>freezer; frost>glass; frost>helicopter; frost>ice; frost>temperature; frost>wind; frost>winter; frown>concentration; frown>confusion; frown>smile; frown>worry; fruit>agriculture; fruit>animal; fruit>apple; fruit>banana; fruit>bean; fruit>berry; fruit>cake; fruit>carrot; fruit>cereal; fruit>cherry; fruit>coconut; fruit>cookie; fruit>cucumber; fruit>evolution; fruit>flower; fruit>grape; fruit>human; fruit>ice cream; fruit>lemon; fruit>mango; fruit>melon; fruit>nutrition; fruit>olive; fruit>pea; fruit>peach; fruit>peanut; fruit>pear; fruit>pineapple; fruit>rice; fruit>rose; fruit>seed; fruit>spice; fruit>strawberry; fruit>tomato; fruit>water; fruit>vegetable; fruit>wheat; fruit>wine; fruit>vinegar; fruit>yogurt; frustration>anger; frustration>confidence; frustration>disappointment; frustration>fear; frying pan>aluminium; frying pan>bacon; frying pan>copper; frying pan>barbecue; fuel>carbon dioxide; fuel>carbon monoxide; fuel>cereal; fuel>coal; fuel>diesel; fuel>earth; fuel>electricity; fuel>energy; fuel>engine; fuel>gas; fuel>global warming; fuel>heating; fuel>kilogram; fuel>star; fuel>wheat; fuel>wood; full stop>punctuation; fun>entertainment; fun>happiness; fun>joy; fun>leisure; fun>pleasure; fun>recreation; fund>funding; funding>donation; funding>finance; funding>investment; funding>money; funding>project; funding>savings; funding>subsidy; funding>tax; funeral>burial; funeral>celebrity; funeral>ceremony; funeral>corpse; funeral>culture; funeral>death; funeral>diamond; funeral>flower; funeral>infant; funeral>religion; funeral>ritual; funeral>science fiction; funeral>tomb; fur>animal; fur>fox; fur>hair; fur>leather; fur>mammal; fur>rabbit; fur>velvet; fur>wool; furniture>house; furniture>oak; furniture>reform; furniture>sculpture; furniture>turkey; futures>architecture; future>art; future>belief; future>death; future>destiny; future>dimension; future>evolution; future>existence; future>fiction; future>ghost; future>god; future>history; future>hope; future>information; future>logic; future>materialism; future>mind; future>music; future>nature; future>optimism; future>painting; future>philosophy; future>poetry; future>prediction; future>present; future>probability; future>reality; future>religion; future>risk; future>robot; future>science fiction; future>sculpture; future>simulation; future>space; future>speed; future>spirit; future>technology; future>theatre; future>theory; future>thesis; future>time; future>uncertainty; future>violence; gadget>electronics; gadget>machine; gadget>novelty; gadget>tool; gain>electronics; gain>ratio; gallery>audience; gallery>balcony; gallery>mining; gallery>retail; gamble>gambling; gambling>coin; gambling>election; gambling>insurance; gambling>law; gambling>lottery; gambling>money; gambling>probability; gambling>recreation; gambling>speculation; gambling>stock; gambling>television; game>art; game>artificial intelligence; game>baseball; game>basketball; game>board game; game>book; game>chess; game>city; game>competition; game>computer; game>cricket; game>dice; game>education; game>enjoyment; game>entertainment; game>exercise; game>gymnastics; game>hunting; game>interaction; game>lawn; game>leather; game>luck; game>marketing; game>money; game>park; game>psychology; game>puzzle; game>school; game>simulation; game>skill; game>sport; game>strategy; game>table tennis; game>tennis; game>town; game>toy; game>training; game>war; game>video game; game>volleyball; gang>harassment; gang>ritual; gang>robbery; gang>terrorist; gang>theft; gang>violence; garden>bird; garden>carbon dioxide; garden>climate change; garden>farm; garden>flower; garden>food; garden>fountain; garden>gardener; garden>gardening; garden>insect; garden>landscape; garden>light; garden>lighting; garden>nature; garden>ocean; garden>opera; garden>paradise; garden>park; garden>plant; garden>pollution; garden>rain; garden>sculpture; garden>season; garden>shed; garden>soil; garden>sunshine; garden>trail; garden>tree; garden>water; garden>wildlife; garden>zoo; gardener>garden; gardener>gardening; gardener>agriculture; gardener>air conditioning; gardener>animal; gardener>ant; gardener>balcony; gardener>basket; gardener>bird; gardener>cat; gardener>civilization; gardener>flower; gardener>fruit; gardener>garden; gardener>herb; gardener>hobby; gardener>hygiene; gardener>insect; gardener>ladder; gardener>lawn; gardener>leaf; gardener>medicine; gardener>plant; gardener>seed; gardener>spade; gardener>tourism; gardener>tree; gardener>weed; gardener>wildlife; gardener>zoo; garlic>antibiotic; garlic>aspirin; garlic>bird; garlic>blood; garlic>bulb; garlic>cancer; garlic>cholesterol; garlic>glass; garlic>infection; garlic>insect; garlic>iron; garlic>juice; garlic>leek; garlic>onion; garlic>oven; garlic>pasta; garlic>pregnancy; garlic>protein; garlic>tomato; garlic>weed; garlic>vinegar; garlic>worm; garment>clothing; gas>air; gas>air conditioning; gas>atmosphere; gas>breath; gas>carbon dioxide; gas>chemist; gas>cooking; gas>density; gas>iron; gas>lighting; gas>lightning; gas>liquid; gas>lung; gas>mixture; gas>momentum; gas>oxygen; gas>parachute; gas>particle; gas>pressure; gas>sailing; gas>smoke; gas>statistics; gas>temperature; gas>weather; gas>wind; gate>border; gate>castle; gate>door; gate>fence; gate>road; gate>wall; gear>friction; gear>ratio; gender>biology; gender>breast; gender>butterfly; gender>chemistry; gender>clothing; gender>disability; gender>discrimination; gender>dna; gender>education; gender>gene; gender>genetics; gender>god; gender>history; gender>intelligence; gender>language; gender>nationality; gender>non; gender>oxygen; gender>protein; gender>psychology; gender>sex; gender>species; gene>ancestor; gene>bacteria; gene>biology; gene>data; gene>dna; gene>electronics; gene>evolution; gene>generation; gene>genetics; gene>hypothesis; gene>infection; gene>life; gene>mouse; gene>pea; gene>protein; gene>region; gene>species; gene>symbol; gene>virus; generalization>animal; generalization>bird; generalization>dog; generalization>fish; generalization>logic; generalization>mammal; generalization>reasoning; generalization>reptile; generalization>triangle; generation>biology; generation>career; generation>child; generation>childhood; generation>grandmother; generation>mother; generation>offspring; generation>reproduction; generation>salary; generosity>gift; generosity>poison; generosity>selfishness; genetics>adaptation; genetics>animal; genetics>bacteria; genetics>biology; genetics>cancer; genetics>dna; genetics>evolution; genetics>gene; genetics>health; genetics>health care; genetics>human; genetics>nutrition; genetics>pea; genetics>plant; genetics>protein; genetics>science; genetics>virus; genius>creativity; genius>evolution; genius>expert; genius>insight; genius>intelligence; genius>person; genius>philosopher; genius>statistics; gentleman>business; gentleman>citizen; gentleman>cricket; gentleman>education; gentleman>family; gentleman>honour; gentleman>irony; gentleman>lady; gentleman>prince; gentleman>salary; gentleman>trade; gentleman>university; gentleman>virtue; geography>art; geography>astronomy; geography>climate; geography>communication; geography>culture; geography>database; geography>earth; geography>economics; geography>geology; geography>globalization; geography>horizon; geography>human; geography>interaction; geography>map; geography>mountain; geography>planet; geography>politics; geography>science; geography>soil; geography>space; geography>sustainability; geography>transport; geography>university; geography>valley; geography>water; geology>atmosphere; geology>climate change; geology>earth; geology>earthquake; geology>erosion; geology>evolution; geology>flood; geology>geography; geology>intrusion; geology>landscape; geology>metal; geology>mining;

geology>mountain; geology>museum; geology>river; geology>science; geology>volcano; gerund>adjective; gerund>adverb; gerund>clause; gerund>infinitive; gerund>noun; gerund>phrase; gerund>preposition; gerund>verb; gesture>dance; gesture>face; gesture>hand; gesture>speech; gesture>word; ghost>analogy; ghost>animal; ghost>classic; ghost>fear; ghost>fiction; ghost>god; ghost>mind; ghost>perception; ghost>religion; ghost>sacrifice; ghost>sleep; ghost>spirit; gift>baby; gift>birthday; gift>boyfriend; gift>bribery; gift>cake; gift>drink; gift>economics; gift>examination; gift>father; gift>food; gift>forgiveness; gift>friendship; gift>funeral; gift>girlfriend; gift>happiness; gift>kindness; gift>love; gift>money; gift>mother; gift>property; gift>retirement; gift>sacrifice; gift>souvenir; gift>student; gift>wedding; giraffe>animal; giraffe>camel; giraffe>leopard; giraffe>lion; giraffe>mammal; giraffe>rib; giraffe>skull; giraffe>tick; giraffe>woodland; girl>adult; girl>boy; girl>childhood; girl>confirmation; girl>education; girl>female; girl>girlfriend; girl>human; girl>man; girl>turkey; girl>woman; girlfriend>boyfriend; girlfriend>friendship; girlfriend>marriage; girlfriend>wedding; glass>bottle; glass>carbon; glass>carbon dioxide; glass>chemical; glass>crystal; glass>lightning; glass>sand; glass>telescope; glass>vase; glass>window; glass>volume; glasses>blindness; glasses>chef; glasses>department store; glasses>ear; glasses>fashion; glasses>glass; glasses>hat; glasses>laser; glasses>light; glasses>pharmacy; glasses>plastic; glasses>radiation; glasses>sunglasses; glasses>virtual reality; global warming>atmosphere; global warming>carbon dioxide; global warming>cloud; global warming>desert; global warming>energy; global warming>extinction; global warming>flood; global warming>ice; global warming>ocean; global warming>ozone; global warming>planet; global warming>plant; global warming>probability; global warming>rice; global warming>satellite; global warming>snow; global warming>society; global warming>soil; global warming>statistics; global warming>summer; global warming>technology; global warming>water; global warming>volcano; globalization>accountant; globalization>airline; globalization>banking; globalization>business; globalization>capitalism; globalization>carbon dioxide; globalization>cash; globalization>climate change; globalization>communication; globalization>community; globalization>construction; globalization>crime; globalization>culture; globalization>curriculum; globalization>democracy; globalization>earth; globalization>economics; globalization>economist; globalization>exchange rate; globalization>famine; globalization>fast food; globalization>finance; globalization>global warming; globalization>habitat; globalization>health; globalization>human rights; globalization>immigration; globalization>import; globalization>income; globalization>industrialization; globalization>innovation; globalization>insurance; globalization>investment; globalization>investor; globalization>knowledge; globalization>leisure; globalization>liberty; globalization>life; globalization>marriage; globalization>nature; globalization>passport; globalization>peasant; globalization>philosophy; globalization>pollution; globalization>propaganda; globalization>recreation; globalization>religion; globalization>river; globalization>socialism; globalization>society; globalization>solidarity; globalization>sustainability; globalization>tax; globalization>technology; globalization>the internet; globalization>tiger; globalization>tourism; globalization>trade; globalization>transport; globalization>transportation; globalization>travel; globalization>war; globalization>wealth; globe>baseball; globe>child; globe>cigarette; globe>confirmation; globe>cricket; globe>cycling; globe>evidence; globe>fashion; globe>finger; globe>garden; globe>gardening; globe>garment; globe>hand; globe>heat; globe>lady; globe>leather; globe>patient; globe>silk; globe>silver; globe>skateboard; globe>ski; globe>steering wheel; globe>thumb; globe>wheelchair; globe>wool; globe>wrist; goal>belief; goal>commerce; goal>cost; goal>customer; goal>emotion; goal>motivation; goal>person; goal>system; goalkeeper>ice hockey; goalkeeper>sport; goal>adolescent; goal>animal; goal>butter; goal>cattle; goal>cheese; goal>cow; goal>curry; goal>devil; goal>erosion; goal>fish; goal>ice cream; goal>iron; goal>litre; goal>mammal; goal>milk; goal>offspring; goal>pet; goal>poverty; goal>religion; goal>saint; goal>sausage; goal>spoon; goal>spoon; goal>starvation; goal>tree; goal>weed; goal>wine; goal>wool; goal>yogurt; goal>angel; goal>body; god>existence; god>faith; god>gender; god>nature; god>necessity; god>plural; god>reason; god>revelation; god>saint; god>simplicity; god>soap opera; god>turkey; god>world; god>worship; gold>aluminium; gold>badge; gold>bronze; gold>cancer; gold>chemistry; gold>coin; gold>computer; gold>copper; gold>currency; gold>electronics; gold>evil; gold>geology; gold>icon; gold>inflation; gold>iron; gold>lead; gold>metal; gold>money; gold>ocean; gold>receipt; gold>satellite; gold>silver; gold>sun; gold>tin; gold>trophy; gold>vehicle; gold>weight; gold>sport; gossip>blackmail; gossip>celebrity; gossip>community; gossip>curiosity; gossip>infomation; gossip>popularity; gossip>reputation; gossip>scandal; gossip>self-esteem; gossip>sin; government>alliance; government>bureaucracy; government>capitalism; government>constitution; government>corruption; government>democracy; government>economics; government>election; government>empire; government>fear; government>hate; government>history; government>hospital; government>human rights; government>jury; government>liberty; government>majority; government>philosophy; government>police; government>policy; government>politics; government>republic; government>school; government>science; government>science fiction; government>socialism; government>synonym; government>terrorist; gram>kilogram; gram>metre; gram>water; grammar>communication; grammar>education; grammar>first language; grammar>learning; grammar>nationality; grammar>observation; grammar>phrase; grammar>primary school; grammar>punctuation; grammar>usage; grandchild>family; granddad>grandparent; granddaughter>family; grandfather>grandparent; grandma>grandparent; grandmother>grandparent; grandpa>grandparent; grandparents>aunt; grandparent>child; grandparent>cousin; grandparent>father; grandparent>gene; grandparent>mother; grandparent>parent; grandparents>plural; grandparents>uncle; grandson>family; granny>grandparent; grape>agriculture; grape>berry; grape>brain; grape>cancer; grape>fruit; grape>heart; grape>jam; grape>nerve; grape>vine; grape>wine; grape>vinegar; grape>virus; graph>chart; graph>diagram; graphics>animation; graphics>art; graphics>brand; graphics>business; graphics>concept; graphics>drawing; graphics>economics; graphics>engineering; graphics>game; graphics>geography; graphics>idea; graphics>illustration; graphics>image; graphics>newspaper; graphics>number; graphics>painting; graphics>paper; graphics>photograph; graphics>poster; graphics>science; graphics>space; graphics>symbol; graphics>video game; graphics>wood; grasp>hand; grass>animal; grass>baseball; grass>beer; grass>cattle; grass>cereal; grass>clothing; grass>construction; grass>cricket; grass>desert; grass>dinosaur; grass>drought; grass>food; grass>fuel; grass>golf; grass>grain; grass>horse; grass>human; grass>kangaroo; grass>lawn; grass>paper; grass>plant; grass>rabbit; grass>rice; grass>sheep; grass>suburb; grass>tennis; grass>wheat; grass>whisky; grass>archaeology; grave>burial; grave>cemetery; grave>culture; grave>pyramid; grave>religion; grave>soul; grave>tomb; greatness>genius; greed>authority; greed>popularity; greed>robbery; green>blue; green>copper; green>devil; green>envy; green>experience; green>firework; green>fish; green>frog; green>gambling; green>grass; green>greed; green>health; green>hope; green>illness; green>insomnia; green>jealousy; green>laser; green>lead; green>leek; green>money; green>nature; green>perception; green>prostitute; green>protein; green>purple; green>red; green>traffic light; green>white; green>yellow; green>youth; greeting>culture; greeting>gesture; greeting>hug; greeting>telephone; greeting>tradition; grey>baseball; grey>black; grey>blue; grey>brain; grey>earth; grey>environmentalist; grey>fog; grey>green; grey>intellectual; grey>lead; grey>pink; grey>prayer; grey>profession; grey>red; grey>religion; grey>speed; grey>white; grey>yellow; grief>deer; grief>elephant; grief>laughter; grief>lion; grief>professor; grief>psychiatrist; grief>psychologist; grief>suicide; grief>terrorism; grill>restaurant; grin>smile; groom>bride; groom>spouse; ground>coffee; ground>law; ground>philosophy; ground>soil; ground>stadium; group>enemy; group>family; group>friend; group>gang; group>immigrant; group>nationality; group>organization; group>supporter; growth>height; growth>interest; growth>money; guard>police; guest>hospitality; guidance>guide; guide>culture; guide>ecology; guide>fishing; guide>hunting; guide>salmon; guide>sport; guide>wilderness; guitar>bone; guitar>brass; guitar>cello; guitar>folk; guitar>jazz; guitar>leather; guitar>plastic; guitar>radio; guitar>ratio; guitar>violin; guitarist>fingernail; guitarist>guitar; guitarist>jazz; guitarist>magazine; guitarist>singing; guitarist>website; gum>chewing gum; gun>sound; gun>weapon; gym>curriculum; gym>education; gym>gymnastics; gymnastics>ballet; gymnastics>dance; gymnastics>sport; habit>habitat; habitat>animal; habitat>plant; habitat>population; habitat>predator; habitat>species; hail>airport; hail>atmosphere; hail>ice; hail>rocket; hail>thunderstorm; hail>tornado; hail>water; hail>wind; hair>blade; hair>cat; hair>communication; hair>dirty; hair>dust; hair>ear; hair>euro; hair>eyebrow; hair>eyelash; hair>face; hair>fur; hair>gender; hair>haircut; hair>hand; hair>mammal; hair>milk; hair>punishment; hair>rain; hair>scissors; hair>sweat; hairdresser>barber; hairdresser>comb; hairdresser>electricity; hairdresser>hair; hairdresser>scissors; hairdresser>slavery; hairdresser>spirit; hall>apartment; hall>architecture; hall>building; hall>castle; hall>college; hall>community; hall>corridor; hall>kitchen; hall>library; hall>office; hall>theatre; hall>university; ham>cholesterol; ham>meat; ham>protein; ham>sandwich; hammer>bone; hammer>force; hammer>muscle; hammer>speed; hammer>tool; hammer>war; hammer>weapon; hammer>wood; hand>animal; hand>bird; hand>dinosaur; hand>evolution; hand>finger; hand>foot; hand>grasp; hand>human; hand>mammal; hand>medicine; hand>monkey; hand>paw; hand>skeleton; hand>thumb; hand>wrist; handbag>coin; handbag>contraception; handbag>crocodile; handbag>mobile phone; handbag>security; handbag>strap; handbag>wallet; handkerchief>cotton; handkerchief>fashion; handkerchief>hand; handkerchief>handbag; handkerchief>hygiene; handkerchief>linen; handkerchief>pocket; handkerchief>silk; handle>gambling; handout>college; handout>gift; handout>homelessness; handout>welfare; handwriting>signature; happiness>biology; happiness>philosophy; happiness>pleasure; happiness>psychology; happiness>religion; happiness>symbol; happiness>well-being; happiness>virtue; harassment>discrimination; hardware>medal; harm>death; harm>disability; harm>law; harm>liberty; harm>pain; harm>pleasure; harm>skill; harm>well-being; harmony>jazz; harmony>melody; harmony>music; harmony>performance; harmony>tradition; harvest>agriculture; harvest>cereal; harvest>crop; harvest>energy; harvest>fish; harvest>farm; harvest>grain; harvest>season; harvest>timber; harvest>wine; hat>cotton; hat>cricket; hat>face; hat>ribbon; hat>sheep; hat>ski; hat>straw; hat>wool; hate>hatred; hatred>anger; hatred>crime; hatred>disability; hatred>discrimination; hatred>emotion; hatred>gender; hatred>gossip; hatred>harassment; hatred>language; hatred>nationality; hatred>prejudice; hatred>religion; hatred>revenge; hatred>sex; hazard>accident; hazard>chemical; hazard>disaster; hazard>emergency; hazard>global warming; hazard>health; hazard>life; hazard>possibility; hazard>property; hazard>punishment; hazard>risk; hazard>volcano; head>brain; head>ear; head>eye; head>face; head>mouth; head>nose; head>taste; headache>anxiety; headache>boy; headache>cancer; headache>child; headache>cough; headache>diary; headache>fever; headache>food; headache>infection; headache>medication; headache>neck; headache>nerves; headache>pain; headache>sleep; headache>stroke; headache>symptom; headache>weather; headache>weather; headache>virus; heading>headline; heading>volleyball; headline>humour; headlines>publisher; headquarters>corporation; headquarters>finance; headquarters>marketing; headquarters>organization; headquarters>turkey; health care>cancer; health care>clinic; health care>diagnosis; health care>disability; health care>disease; health care>donation; health care>health; health care>hospital; health care>illness; health care>insurance; health care>medicine; health care>nurse; health care>pharmacist; health care>pharmacy; health care>professional; health care>regulation; health care>surgery; health care>vaccination; health care>wheelchair; health>air; health>alcohol; health>biology; health>body; health>child; health>continent; health>country; health>culture; health>disease; health>education; health>exercise; health>gender; health>genetics; health>health care; health>house; health>human; health>hygiene; health>illness; health>injury; health>literacy; health>manufacturing; health>medicine; health>nutrition; health>obesity; health>outbreak; health>pain; health>person; health>pharmacy; health>physics; health>psychology; health>research; health>safety; health>sleep; health>smoking; health>vaccination; health>water; health>well-being; health>world; heart>animal; heart>bird; heart>blood; heart>copper; heart>crab; heart>fat; heart>insect; heart>iron; heart>liver; heart>lung; heart>mammal; heart>muscle; heart>protein; heart>reptile; heart>spider; heart>sugar; heart>vein; heart>chemistry; heart>energy; heart>engineering; heart>kilogram; heart>life; heart>physics; heat>steam; heat>sun; heat>temperature; heat>thermometer; heaven>angel; heaven>earth; heaven>faith; heaven>fiction; heaven>god; heaven>hell; heaven>nature; heaven>paradise; heaven>prayer; heaven>science fiction; heaven>sin; heaven>sky; heaven>virtue; hedge>century; hedge>count; hedge>fence; hedge>flower; hedge>garden; hedge>privacy; hedge>road; hedge>wildlife; heel>foot; heel>knee; height>dimension; height>distance; height>genetics; height>length; height>mountain; height>nutrition; height>pi; height>statistics; height>width; heir>inheritance; helicopter>ambulance; helicopter>flight; helicopter>mechanic; helicopter>recreation; helicopter>tourism; helicopter>transport; hell>atmosphere; hell>cartoon; hell>death; hell>devil; hell>earth; hell>fantasy; hell>god; hell>heaven; hell>hypocrisy; hell>paradise; hell>punishment; hell>religion; hell>hell; hell>hell; hell>soul; hell>torture; helmet>arrow; helmet>bronze; helmet>cap; helmet>construction; helmet>iron; helmet>leather; helmet>mining; helmet>plastic; helmet>steel; helmet>straw; helmet>sunglasses; helmet>sword; helmet>tank; help>emergency; herb>bark; herb>berry; herb>flower; herb>food; herb>fruit; herb>leaf; herb>religion; herb>root; herb>seed; herb>spice; herb>tree; herb>vegetable; heritage>birth; heritage>inheritance; hero>archaeology; hero>biography; hero>civilization; hero>courage; hero>endurance; hero>economics; hero>fantasy; hero>film; hero>geography; hero>globalization; hero>protagonist; hero>quest; hero>warrior; hesitation>pause; hierarchy>animation; hierarchy>atom; hierarchy>authority; hierarchy>carbon; hierarchy>chest; hierarchy>colleague; hierarchy>complexity; hierarchy>concept; hierarchy>diagram; hierarchy>diamond; hierarchy>dimension; hierarchy>entity; hierarchy>god; hierarchy>government; hierarchy>hand; hierarchy>heir; hierarchy>hell; hierarchy>human; hierarchy>importance; hierarchy>individual; hierarchy>inheritance; hierarchy>learning; hierarchy>matter; hierarchy>music; hierarchy>nation; hierarchy>nature; hierarchy>object; hierarchy>organization; hierarchy>parent; hierarchy>structure; hierarchy>supervisor; hierarchy>system; hierarchy>triangle; hierarchy>university; hierarchy>verb; hill>cheese; hill>erosion; hill>geology; hill>golf; hill>mountain; hill>soil; hill>volcano; hip>birth; hip>fashion; hip>joint; hip>shoulder; historian>archaeology; historian>economics; historian>narrative; historian>philosophy; historian>politics; historian>psychology; historian>seminar; history>archaeology; history>art; history>communication; history>continent; history>credibility; history>culture; history>decade; history>economics; history>evidence; history>experience; history>fantasy; history>gender; history>geography; history>historian; history>imagination; history>information; history>integrity; history>legend; history>memory; history>narrative; history>philosophy; history>poetry; history>politics; history>poverty; history>propaganda; history>reason; history>science; history>theory; hobby>air conditioning; hobby>amateur; hobby>art; hobby>balcony; hobby>book; hobby>climbing; hobby>comic; hobby>cooking; hobby>dancing; hobby>digestion; hobby>enthusiasm; hobby>fire; hobby>fishing; hobby>garden; hobby>gardener; hobby>gardening; hobby>heating; hobby>hill; hobby>house; hobby>journalism; hobby>label; hobby>landscape; hobby>leisure; hobby>literature; hobby>magazine; hobby>newspaper; hobby>park; hobby>photography; hobby>pottery; hobby>professional; hobby>recreation; hobby>robot; hobby>singing; hobby>tool; hobby>tourism; hobby>trail; hobby>vocabulary; hockey>ball;

hockey>disability; hockey>ice hockey; hockey>sport; hockey>tennis; hold>grasp; hole>opening; holiday>faith; holiday>religion; home>apartment; home>city; home>cooking; home>country; home>emotion; home>family; home>habitat; home>hat; home>homelessness; home>household; home>institution; home>prison; home>residence; home>safety; home>suburb; home>town; homelessness>airport; homelessness>bus; homelessness>caf e; homelessness>college; homelessness>disability; homelessness>disaster; homelessness>dissertation; homelessness>earthquake; homelessness>hotel; homelessness>hypocrisy; homelessness>litter; homelessness>male; homelessness>park; homelessness>poverty; homelessness>prison; homelessness>running; homelessness>tent; homelessness>unemployment; homelessness>van; homelessness>war; homework>computer; homework>education; homework>essay; homework>learning; homework>research; homework>school; homework>student; homework>teacher; homework>teaching; homework>writing; honesty>fair; honesty>integrity; honesty>lie; honesty>loyalty; honesty>proverb; honesty>sincerity; honesty>truth; honey>acid; honey>bee; honey>beer; honey>bread; honey>cooking; honey>cotton; honey>crystal; honey>density; honey>dust; honey>food; honey>glass; honey>ladder; honey>milk; honey>pollution; honey>solution; honey>sugar; honey>symbol; honey>tea; honey>turkey; honey>water; honey>vitamin; honeymoon>pleasure; honeymoon>wedding; honour>cash; honour>celebrity; honour>conscience; honour>crime; honour>culture; honour>dignity; honour>family; honour>frontier; honour>gang; honour>government; honour>individual; honour>integrity; honour>law; honour>love; honour>lyrics; honour>medal; honour>nation; honour>privilege; honour>property; honour>rape; honour>reputation; honour>revenge; honour>school; honour>shame; honour>society; honour>stereotype; honour>turkey; honour>virtue; hope>disappointment; hope>fantasy; hope>fear; hope>heaven; hope>optimism; hope>psychology; horizon>circle; horizon>communication; horizon>dawn; horizon>earth; horizon>landscape; horizon>radio; horizon>sky; horizon>storey; horn>saddle; horn>telephone; horse>advertising; horse>animal; horse>ankle; horse>cello; horse>cereal; horse>concept; horse>donkey; horse>extinction; horse>family; horse>farm; horse>gene; horse>genetics; horse>heel; horse>instinct; horse>mammal; horse>pony; horse>prison; horse>reptile; horse>saddle; horse>stable; horse>vaccination; horse>water; horse>violin; horse>wrist; hospital>ambulance; hospital>business; hospital>campus; hospital>cathedral; hospital>clinic; hospital>diagnosis; hospital>disease; hospital>grammar; hospital>health; hospital>health care; hospital>hospitality; hospital>hostel; hospital>hotel; hospital>injury; hospital>mosque; hospital>nurse; hospital>partnership; hospital>patient; hospital>surgeon; hospital>surgery; hospitality>entertainment; host>hospitality; host>presenter; hostage>crime; hostage>employer; hostage>government; hostage>metaphor; hostage>police officer; hostage>terrorism; hostage>turkey; hostel>carnival; hostel>castle; hostel>climbing; hostel>travel; hostility>aggression; hostility>anger; hostility>denial; hostility>synonym; hotel>air conditioning; hotel>cave; hotel>definite article; hotel>hostel; hotel>investor; hotel>resort; hotel>telephone; hotel>tourism; hour>century; hour>clock; hour>energy; hour>minute; hour>opera; hour>public transport; hour>second; hour>speed; hour>tide; hour>time; hour>wage; house>architect; house>architecture; house>basement; house>bathroom; house>bedroom; house>brick; house>building; house>comfort; house>concrete; house>construction; house>dining room; house>door; house>earthquake; house>economics; house>family; house>fireplace; house>hall; house>home; house>household; house>human; house>kitchen; house>lead; house>library; house>living room; house>loft; house>office; house>pet; house>privacy; house>prosperity; house>shower; house>staircase; house>technology; house>television; house>toilet; house>weather; house>wildlife; house>>window; house>wood; house>workshop; households>disability; household>employment; household>family; household>government; household>home; household>housework; household>income; household>inheritance; household>living room; household>meal; housewife>career; housewife>cooking; housewife>economist; housewife>employment; housewife>factory; housewife>family; housewife>farming; housewife>fruit; housewife>grain; housewife>home; housewife>homework; housewife>household; housewife>nutrition; housewife>rice; housewife>sewing; housewife>vegetable; housewife>volunteer; housing>home; housing>house; hug>affection; hug>am; hug>child; hug>dog; hug>doll; hug>friendship; hug>greeting; hug>hip; hug>kiss; hug>love; hug>sympathy; human rights>abortion; human rights>belief; human rights>capitalism; human rights>child; human rights>climate change; human rights>concept; human rights>contraception; human rights>discrimination; human rights>education; human rights>justice; human rights>peace; human rights>religion; human rights>right; human rights>slavery; human rights>socialism; human rights>treaty; human rights>violence; human rights>woman; human rights>worship; human>adult; human>agriculture; human>aircraft; human>archaeology; human>art; human>artificial intelligence; human>belief; human>boy; human>bureaucracy; human>buyer; human>childhood; human>city; human>civilization; human>climate change; human>clothing; human>comedy; human>commodity; human>communication; human>competition; human>consciousness; human>construction; human>continent; human>cooking; human>crime; human>culture; human>democracy; human>digestion; human>discipline; human>discussion; human>drama; human>dream; human>duty; human>earnings; human>earring; human>earth; human>economics; human>empire; human>entertainment; human>envy; human>evolution; human>exercise; human>existence; human>family; human>female; human>fire; human>gene; human>genetics; human>girl; human>global warming; human>globalization; human>god; human>government; human>hair; human>happiness; human>hate; human>health; human>hierarchy; human>humanity; human>hunting; human>idea; human>incentive; human>information; human>jealousy; human>language; human>law; human>literature; human>logic; human>love; human>male; human>mammal; human>man; human>manufacturing; human>market; human>marriage; human>mind; human>mobile phone; human>motivation; human>narrative; human>nation; human>obesity; human>painting; human>perception; human>philosopher; human>philosophy; human>pleasure; human>politics; human>pollution; human>pottery; human>privilege; human>psychology; human>question; human>racism; human>reason; human>reasoning; human>religion; human>reproduction; human>revolution; human>ritual; human>science; human>self-awareness; human>seller; human>sense; human>sleep; human>society; human>soldier; human>soul; human>space; human>species; human>spirit; human>suffering; human>technology; human>thought; human>tool; human>trade; human>tragedy; human>transport; human>tribe; human>wealth; human>vegetarian; human>violence; human>woman; human>humanity>human; humility>god; humility>heaven; humility>pride; humility>strategy; humility>truth; humility>virtue; humility>wisdom; humour>ambiguity; humour>amusement; humour>comedy; humour>contradiction; humour>culture; humour>education; humour>intelligence; humour>irony; humour>laughter; humour>metaphor; humour>paradox; humour>psychology; humour>reality; humour>smile; hunger>disease; hunger>famine; hunger>food; hunger>starvation; hunting>arrow; hunting>bat; hunting>bear; hunting>bone; hunting>deer; hunting>environmentalist; hunting>extinction; hunting>fish; hunting>fishing; hunting>fox; hunting>fur; hunting>habitat; hunting>infrastructure; hunting>jungle; hunting>language; hunting>lead; hunting>lion; hunting>mammal; hunting>pig; hunting>predator; hunting>prison; hunting>protein; hunting>rabbit; hunting>recreation; hunting>regulation; hunting>ritual; hunting>trophy; hunting>webcam; hunting>wildlife; hunting>wolf; husband>authority; husband>crime; husband>divorce; husband>father; husband>male; husband>marriage; husband>profession; husband>society; husband>spouse; husband>wedding; husband>wife; hygiene>acne; hygiene>bandage; hygiene>cap; hygiene>cold; hygiene>cooking; hygiene>culture; hygiene>cutlery; hygiene>flu; hygiene>gender; hygiene>hairstresser; hygiene>health; hygiene>perfume; hygiene>scent; hygiene>shower; hygiene>soap; hygiene>surgery; hygiene>toilet; hyphen>adjective; hyphen>adverb; hyphen>comma; hyphen>dash; hyphen>punctuation; hyphen>recreation; hyphen>sumname; hyphen>syllable; hyphen>word; hypocrisy>paradox; hypothesis>calculation; hypothesis>concept; hypothesis>entity; hypothesis>experience; hypothesis>experiment; hypothesis>explanation; hypothesis>laboratory; hypothesis>logic; hypothesis>nature; hypothesis>observation; hypothesis>phenomenon; hypothesis>prediction; hypothesis>proposition; hypothesis>reasoning; hypothesis>research; hypothesis>theory; hypothesis>virtue; ice cream>chocolate; ice cream>cream; ice cream>crystal; ice cream>dessert; ice cream>juice; ice cream>milk; ice cream>pension; ice cream>protein; ice cream>sugar; ice cream>yogurt; ice hockey>cricket; ice hockey>ice skating; ice hockey>recreation; ice hockey>rubber; ice skating>emporer; ice skating>helmet; ice skating>ice; ice skating>ice hockey; ice skating>steel; ice>air; ice>atom; ice>carbon dioxide; ice>cloud; ice>crystal; ice>density; ice>fog; ice>frost; ice>hall; ice>heat; ice>iceberg; ice>ice skating; ice>lake; ice>liquid; ice>metal; ice>oxygen; ice>road; ice>soil; ice>thunderstorm; ice>truck; ice>water; ice>>window; iceberg>density; iceberg>erosion; iceberg>satellite; icon>angel; icon>miracle; icon>paper; icon>peasant; icon>saint; icon>symbol; idea>concept; idea>creativity; idea>evolution; idea>experiment; idea>fish; idea>gene; idea>horse; idea>human; idea>image; idea>imagination; idea>liberty; idea>man; idea>memory; idea>perception; idea>property; idea>psychologist; idea>selection; idea>understanding; idea>woman; identity>entity; idiom>clich e; idiom>collocation; idiom>definition; idiom>verb; idiot>democracy; idiot>government; idiot>ignorance; idiot>stupidity; idol>worship; ignorance>awareness; ignorance>innocence; ignorance>knowledge; ignorance>literacy; ignorance>stupidity; ignorance>wisdom; illusion>perception; illusion>sense; illusion>sound; illustration>diagram; illustration>drawing; illustration>image; illustration>ink; illustration>painting; illustration>pen; illustration>photograph; illustration>video game; image>animation; image>camera; image>dimension; image>drawing; image>film; image>graphics; image>map; image>mirror; image>painting; image>paper; image>person; image>photograph; image>photography; image>statue; image>telescope; image>video; imagination>art; imagination>belief; imagination>creativity; imagination>fantasy; imagination>fear; imagination>fiction; imagination>hypothesis; imagination>idea; imagination>language; imagination>mind; imagination>myth; imagination>narrative; imagination>perception; imagination>pleasure; imagination>probability; imagination>psychology; imagination>science fiction; imagination>suffering; imagination>truth; imitation>animal; imitation>curiosity; imitation>empathy; imitation>experiment; imitation>information; imitation>intelligence; imitation>intention; imitation>learning; imitation>purpose; imitation>rat; imitation>reproduction; imitation>science; imitation>scientist; imitation>species; immigrant>immigration; immigration>arrest; immigration>citizen; immigration>climate; immigration>constitution; immigration>education; immigration>employment; immigration>human rights; immigration>poverty; immigration>racism; immigration>refugee; immigration>retirement; immigration>terrorism; immigration>tourist; immigration>war; immigration>welfare; immune system>acid; immune system>animal; immune system>antibiotic; immune system>bacteria; immune system>blood; immune system>cancer; immune system>cough; immune system>disease; immune system>evolution; immune system>fever; immune system>gene; immune system>infant; immune system>infection; immune system>insect; immune system>irritation; immune system>leaf; immune system>lung; immune system>mammal; immune system>medicine; immune system>obesity; immune system>plant; immune system>pregnancy; immune system>skin; immune system>stomach; immune system>vaccination; immune system>vaccine; immune system>virus; immune system>yogurt; impatience>patience; implementation>bureaucracy; implementation>code; implementation>design; implementation>plan; implementation>policy; implementation>solution; implementation>specification; implementation>system; import>commodity; import>consumer; import>customs; import>export; import>income; import>manufacturer; import>price; import>trade; impossibility>contract; impossibility>necessity; imprisonment>liberty; incentive>competition; incentive>corporation; incentive>curiosity; incentive>employment; incentive>slavery; incentive>volunteer; inch>centimetre; inch>length; inch>metre; inch>millimetre; inch>yard; income>economics; income>education; income>peace; income>society; independence>authority; independence>country; independence>nation; independence>revolution; independence>status; independence>violence; indication>sign; individual>biology; individual>consciousness; individual>gene; individual>independence; individual>law; individual>person; individual>philosophy; individual>selection; individual>statistics; individuality>individual; industry>agriculture; industry>carriage; industry>coal; industry>computer; industry>economy; industry>electricity; industry>finance; industry>manufacturing; industry>market; industry>pollution; industry>robot; industry>steel; infancy>infant; infant>adaptation; infant>bruise; infant>health; infant>hospital; infant>human; infant>infection; infant>milk; infant>offspring; infant>pregnancy; infant>toddler; infection>antibiotic; infection>bacteria; infection>blood; infection>body; infection>disease; infection>fever; infection>hygiene; infection>immune system; infection>joint; infection>mammal; infection>medicine; infection>symptom; infection>vaccination; infection>virus; infection>wound; infinitive>adverb; infinitive>clause; infinitive>gerund; infinitive>grammar; infinitive>noun; infinitive>verb; inflation>commodity; inflation>currency; inflation>demand; inflation>economics; inflation>economy; inflation>exchange rate; inflation>infrastructure; inflation>investment; inflation>recession; inflation>scarcity; inflation>stock; inflation>stock market; inflation>unemployment; information>bit; information>cd-rom; information>communication; information>complexity; information>concept; information>data; information>dna; information>education; information>energy; information>feedback; information>form; information>knowledge; information>message; information>perception; information>physics; information>prediction; information>proposition; information>relevance; information>sequence; information>system; information>thought; information>uncertainty; information>understanding; infrastructure>airline; infrastructure>ambulance; infrastructure>architect; infrastructure>architecture; infrastructure>bridge; infrastructure>bus; infrastructure>business; infrastructure>city; infrastructure>climate change; infrastructure>coal; infrastructure>college; infrastructure>commerce; infrastructure>communication; infrastructure>consent; infrastructure>contract; infrastructure>corporation; infrastructure>cost; infrastructure>earthquake; infrastructure>economy; infrastructure>electricity; infrastructure>energy; infrastructure>exchange; infrastructure>factory; infrastructure>ferry; infrastructure>government; infrastructure>health care; infrastructure>hospital; infrastructure>institution; infrastructure>library; infrastructure>manufacturing; infrastructure>market; infrastructure>mobile phone; infrastructure>museum; infrastructure>nation; infrastructure>noise; infrastructure>organization; infrastructure>ownership; infrastructure>park; infrastructure>police; infrastructure>port; infrastructure>poverty; infrastructure>primary school; infrastructure>public transport; infrastructure>radio; infrastructure>recreation; infrastructure>road; infrastructure>school; infrastructure>secondary school; infrastructure>society; infrastructure>software; infrastructure>storm; infrastructure>sustainability; infrastructure>telecommunications; infrastructure>telephone; infrastructure>television; infrastructure>traffic light; infrastructure>trail; infrastructure>tram; infrastructure>transport; infrastructure>tunnel; infrastructure>university; infrastructure>water; infrastructure>weapon; infrastructure>vehicle; infrastructure>wheel; ingredient>cooking; ingredient>law; ingredient>mixture; ingredient>recipe; inheritance>death; inheritance>debt; inheritance>god; inheritance>government; inheritance>individual; inheritance>myth; inheritance>northeast; inheritance>property; inheritance>sex; inheritance>turkey; initial>paragraph; initiative>referendum; injury>accident; injury>bruise; injury>bruise; injury>skin; injury>suicide; injury>war; injury>violence; injury>wound; injustice>justice; ink>brush; ink>crystal; ink>design; ink>image; ink>liquid; ink>pen; ink>sustainability; ink>writing; innocence>child; innocence>crime; innocence>evil; innocence>experience; innocence>fiction; innocence>guilt; innocence>ignorance; innocence>sin; innocence>white; innovation>business; innovation>capitalism; innovation>carbon

footprint; innovation>comfort; innovation>commerce; innovation>convenience; innovation>creativity; innovation>design; innovation>economics; innovation>education; innovation>efficiency; innovation>energy; innovation>engineering; innovation>globalization; innovation>government; innovation>hospital; innovation>idea; innovation>immigration; innovation>improvement; innovation>infrastructure; innovation>invention; innovation>manufacturing; innovation>market; innovation>material; innovation>productivity; innovation>regulation; innovation>research; innovation>society; innovation>technology; innovation>transportation; input>information; input>output; input>system; inquiry>analogy; inquiry>certainty; inquiry>curiosity; inquiry>diagnosis; inquiry>doubt; inquiry>hypothesis; inquiry>knowledge; inquiry>logic; inquiry>uncertainty; insect>adult; insect>agriculture; insect>animal; insect>ant; insect>bat; insect>bee; insect>bird; insect>blood; insect>butterfly; insect>carbon dioxide; insect>crab; insect>digestion; insect>evolution; insect>fat; insect>fly; insect>fruit; insect>genetics; insect>head; insect>honey; insect>human; insect>lung; insect>male; insect>mouth; insect>nutrition; insect>oxygen; insect>plant; insect>protein; insect>recycling; insect>robot; insect>sense; insect>silks; insect>species; insect>spider; insect>stomach; insect>wasp; insect>vein; insect>wheel; insect>security>risk; insect>security>security; insight>artificial intelligence; insight>brand; insight>cause; insight>consumer; insight>fluency; insight>marketing; insight>mind; insight>perception; insight>psychology; insight>sleep; insomnia>anxiety; insomnia>disease; insomnia>fear; insomnia>herb; insomnia>longevity; insomnia>pain; insomnia>sleep; insomnia>withdrawal; inspection>document; inspection>review; inspection>x-ray; inspector>captain; inspector>detective; inspector>fraud; inspector>police; inspector>police station; inspiration>invention; instinct>aggression; instinct>consciousness; instinct>learning; instinct>life; instinct>mammal; instinct>motivation; instinct>nest; instinct>psychology; instinct>sex; institute>research; institute>university; institution>art; institution>behaviour; institution>business; institution>capitalism; institution>cooperation; institution>corporation; institution>country; institution>court; institution>culture; institution>economics; institution>education; institution>factory; institution>family; institution>government; institution>health care; institution>hospital; institution>individual; institution>industry; institution>institute; institution>judge; institution>language; institution>law; institution>marriage; institution>medicine; institution>money; institution>nation; institution>police; institution>prison; institution>religion; institution>research; institution>role; institution>school; institution>society; institution>university; instructor>teacher; instructor>professor; instructor>teacher; instrument>tool; insult>rudeness; insurance>advertising; insurance>aircraft; insurance>airport; insurance>basketball; insurance>business; insurance>cash; insurance>community; insurance>contract; insurance>credit card; insurance>death; insurance>decade; insurance>disability; insurance>disaster; insurance>discrimination; insurance>earthquake; insurance>education; insurance>family; insurance>fire; insurance>funeral; insurance>gambing; insurance>gender; insurance>golf; insurance>horse; insurance>investment; insurance>loan; insurance>market; insurance>millennium; insurance>money; insurance>pension; insurance>politics; insurance>probability; insurance>profession; insurance>regulation; insurance>religion; insurance>retirement; insurance>revolution; insurance>saving; insurance>speculation; insurance>statistics; insurance>tax; insurance>terrorism; insurance>theft; insurance>tornado; insurance>unemployment; insurance>wage; insurance>wealth; insurance>weather; insurance>volcano; integration>integrity; integrity>accuracy; integrity>bias; integrity>business; integrity>consciousness; integrity>doubt; integrity>honesty; integrity>hypocrisy; integrity>hypothesis; integrity>medicine; integrity>mind; integrity>politics; integrity>virtue; intellect>human; intellect>intellectual; intellect>intelligence; intellect>knowledge; intellect>logic; intellect>mind; intellect>profession; intellect>psychology; intellect>reality; intellect>truth; intellect>understanding; intellectual>art; intellectual>authority; intellectual>capitalism; intellectual>critic; intellectual>culture; intellectual>engineering; intellectual>essay; intellectual>evolution; intellectual>genetics; intellectual>intelligence; intellectual>journalist; intellectual>literacy; intellectual>literature; intellectual>medicine; intellectual>philosophy; intellectual>profession; intellectual>reason; intellectual>scholar; intellectual>socialism; intellectual>technology; intellectual>thought; intelligence>artificial intelligence; intelligence>bird; intelligence>communication; intelligence>definition; intelligence>dolphin; intelligence>elephant; intelligence>human; intelligence>knowledge; intelligence>learning; intelligence>mammal; intelligence>memory; intelligence>music; intelligence>parrot; intelligence>plan; intelligence>psychology; intelligence>reason; intelligence>science fiction; intelligence>scientist; intelligence>self-awareness; intelligence>understanding; intent>intention; intention>goal; intention>pyramid; interaction>feedback; interaction>gene; interaction>medication; interaction>medicine; interaction>physics; interaction>protein; interaction>science; interaction>statistics; interest>asset; interest>fee; interest>inflation; interest>money; interest>return; interest>spreadsheet; interest>theft; intervention>invasion; interview>question; intruder>intrusion; intrusion>earth; intrusion>erosion; intrusion>glass; intrusion>planet; intrusion>volcano; invasion>aggression; invasion>aircraft; invasion>archaeology; invasion>border; invasion>castle; invasion>city; invasion>coast; invasion>combat; invasion>communication; invasion>economics; invasion>entity; invasion>gold; invasion>government; invasion>infrastructure; invasion>navy; invasion>parachute; invasion>peace; invasion>philosophy; invasion>port; invasion>propaganda; invasion>radio; invasion>religion; invasion>river; invasion>silver; invasion>slavery; invasion>starvation; invasion>strategy; invasion>tank; invasion>technology; invasion>town; invasion>transportation; invasion>treaty; invasion>tribute; invasion>war; invasion>warrior; invention>architecture; invention>art; invention>creativity; invention>design; invention>experiment; invention>flight; invention>machine; invention>parachute; invention>photography; invention>train; inventor>invention; investigation>detective; investigation>disease; investigation>research; investigator>detective; investigator>inspector; investment>asset; investment>bank; investment>economics; investment>economy; investment>factory; investment>finance; investment>gambing; investment>inflation; investment>insurance; investment>money; investment>risk; investment>speculation; investment>stock; investor>antique; investor>art; investor>business; investor>commodity; investor>currency; investor>investment; investor>stock; iron>agriculture; iron>aluminium; iron>bean; iron>bread; iron>building; iron>carbon; iron>carbon dioxide; iron>carbon monoxide; iron>copper; iron>dna; iron>earth; iron>fish; iron>heart; iron>liver; iron>mammal; iron>metal; iron>mining; iron>oxygen; iron>paint; iron>road; iron>sand; iron>ship; iron>steel; iron>wreath; ironing>cotton; ironing>linen; ironing>silks; ironing>washing machine; ironing>wool; ironing>wrinkle; ironing>coward; ironing>genius; ironing>hypocrisy; ironing>intelligence; ironing>legend; ironing>love; ironing>paradox; irritation>alcohol; irritation>biology; irritation>empathy; irritation>immune system; irritation>mammal; irritation>monkey; irritation>obesity; irritation>pain; irritation>perception; irritation>rash; irritation>sense; irritation>tobacco; island>concrete; island>continent; island>coral; island>desert; island>geography; island>sand; island>tourism; island>waste; island>water; island>volcano; isolation>solitude; issue>child; issue>journal; issue>magazine; issue>newspaper; jacket>baseball; jacket>chemistry; jacket>denim; jacket>fashion; jacket>garment; jacket>hunting; jacket>raincoat; jacket>sailor; jacket>scientist; jacket>sleeve; jacket>student; jacket>sweater; jacket>waist; jail>prison; january>february; january>march; january>oak; january>summer; january>winter; january>year; jar>bottle; jargon>bit; jargon>capitalism; jargon>philosopher; jargon>slang; jaw>bone; jaw>fish; jaw>mouth; jaw>tooth; jazz>arrangement; jazz>harmony; jazz>melody; jazz>piano; jazz>singer; jazz>slavery; jazz>violin; jealousy>adult; jealousy>anger; jealousy>competition; jealousy>disgust; jealousy>emotion; jealousy>empathy; jealousy>envy; jealousy>feeling; jealousy>psychologist; jealousy>resentment; jealousy>self-esteem; jealousy>synonym; jealousy>thought; jeans>copper; jeans>denim; jeans>teenager; jeans>trousers; jeans>turkey; jewels>jewellery; jewellery>archaeologist; jewellery>archaeology; jewellery>bone; jewellery>bracelet; jewellery>bronze; jewellery>coin; jewellery>copper; jewellery>culture; jewellery>diamond; jewellery>earring; jewellery>feather; jewellery>glass; jewellery>gold; jewellery>marriage; jewellery>metal; jewellery>necklace; jewellery>perfume; jewellery>plastic; jewellery>silver; jewellery>turkey; jewellery>wood; jogging>running; joint>bone; joint>infection; joint>knee; joint>suffix; joint>wrist; joke>clown; joke>comedy; joke>disability; joke>elephant; joke>humour; joke>irony; joke>laughter; joke>literature; joke>nonsense; joke>paradox; joke>poetry; joke>racist; joke>rhythm; joke>science; joke>sex; joke>smile; joke>stereotype; journal>diary; journal>journalism; journal>journalist; journal>magazine; journal>newspaper; journal>parliament; journal>accuracy; journal>democracy; journal>disability; journal>discrimination; journal>newspaper; journal>religion; journal>truth; journal>war; journal>combat; journal>critic; journal>information; journal>interview; journal>journalism; journal>microphone; journal>murder; journal>news; journal>photography; journal>research; journal>turkey; journey>travel; joy>happiness; judge>black; judge>chancellor; judge>court; judge>jury; judge>law; judge>lawyer; judge>magistrate; judge>politics; judge>profession; judge>professor; judge>prosecutor; judge>red; judge>referee; judge>solicitor; jug>breast; jug>kettle; jug>prison; juice>bacteria; juice>caf ; juice>fruit; juice>liquid; juice>meat; juice>soft drink; juice>stroke; july>month; july>summer; july>winter; jump>assault; jumper>sweater; june>day; june>december; june>month; june>rose; june>summer; june>winter; june>year; jungle>rainforest; jungle>wilderness; junk food>chewing gum; junk food>dessert; junk food>fast food; junk food>fat; junk food>pizza; junk food>salt; junk food>slang; junk food>sugar; junk food>waste; junk>scrap; junk>waste; junk>woman; jury>abortion; jury>assault; jury>bribery; jury>competition; jury>court; jury>crime; jury>evidence; jury>judge; jury>justice; jury>murder; jury>prosecutor; jury>slavery; jury>terrorism; jury>trial; jury>verdict; justice>bias; justice>contract; justice>crime; justice>culture; justice>destiny; justice>disability; justice>discrimination; justice>gender; justice>generosity; justice>history; justice>human rights; justice>injustice; justice>judge; justice>jury; justice>law; justice>lawyer; justice>mercy; justice>nation; justice>need; justice>politician; justice>prison; justice>property; justice>punishment; justice>religion; justice>respect; justice>revenge; justice>slavery; justice>theft; justice>wealth; justice>verdict; kangaroo>animal; kangaroo>carbon dioxide; kangaroo>extinction; kangaroo>mammal; kangaroo>mouse; kangaroo>predator; kangaroo>protein; kangaroo>reptile; kangaroo>species; kangaroo>windscreen; keeper>goalkeeper; kettle>salmon; kettle>whistle; key>chart; kick>foot; kick>knee; kid>child; kidney>adaptation; kidney>adjective; kidney>bean; kidney>bird; kidney>blood; kidney>carbon dioxide; kidney>conscience; kidney>cooking; kidney>fish; kidney>liver; kidney>mammal; kidney>protein; kidney>reptile; kidney>rib; kidney>water; killer>murderer; killing>death; kilo>kilogram; kilogram>carbon; kilogram>credit card; kilogram>density; kilogram>energy; kilogram>force; kilogram>gold; kilogram>gram; kilogram>lead; kilogram>litre; kilogram>metre; kilogram>millimetre; kilogram>ounce; kilogram>pressure; kilogram>uncertainty; kilogram>weight; kilometre>cycling; kilometre>length; kilometre>metre; kilometre>mile; kilometre>millimetre; kilometre>slang; kilometre>yard; kind>kindness; kindness>disposition; kindness>emotion; kindness>empathy; kindness>envy; kindness>generosity; kindness>love; kindness>sympathy; kindness>virtue; kingdom>realm; kiss>adolescent; kiss>affection; kiss>cholesterol; kiss>friendship; kiss>greeting; kiss>hug; kiss>lip; kiss>love; kiss>luck; kiss>muscle; kiss>peace; kiss>prayer; kiss>respect; kiss>temple; kiss>tongue; kiss>wedding; kit>collection; kit>component; kit>fox; kit>kitten; kit>rabbit; kit>rabbit; kitchen>apartment; kitchen>architect; kitchen>art; kitchen>basement; kitchen>bathroom; kitchen>brass; kitchen>bronze; kitchen>camping; kitchen>castle; kitchen>catering; kitchen>chimney; kitchen>climate; kitchen>coal; kitchen>cooking; kitchen>copper; kitchen>cupboard; kitchen>dining room; kitchen>dishwasher; kitchen>electricity; kitchen>factory; kitchen>fast food; kitchen>fire; kitchen>fireplace; kitchen>flour; kitchen>hall; kitchen>hospital; kitchen>hotel; kitchen>industrialization; kitchen>iron; kitchen>laboratory; kitchen>laundry; kitchen>mansion; kitchen>oven; kitchen>pottery; kitchen>pump; kitchen>railway; kitchen>restaurant; kitchen>rice; kitchen>ship; kitchen>sink; kitchen>slavery; kitchen>smoke; kitchen>society; kitchen>staircase; kitchen>steak; kitchen>triangle; kitchen>wood; kitchen>yacht; kite>aircraft; kite>art; kite>ballet; kite>beach; kite>cotton; kite>electricity; kite>force; kite>lightning; kite>linen; kite>observation; kite>paper; kite>recreation; kite>rope; kite>silks; kitten>birth; kitten>cat; kitten>eye; kitten>female; kitten>male; kitten>puppy; knee>baby; knee>bone; knee>joint; knee>surgery; knee>thigh; knee>x-ray; knife>blade; knife>bread; knife>bronze; knife>carbon; knife>copper; knife>cooking; knife>cutter; knife>fish; knife>fork; knife>iron; knife>leather; knife>meat; knife>pillow; knife>plastic; knife>produce; knife>ritual; knife>rubber; knife>spoon; knife>steel; knife>surgery; knife>sword; knife>wood; knob>mountain; knot>chain; knot>climbing; knot>donkey; knot>joke; knot>puzzle; knot>rope; knot>strap; knowledge>belief; knowledge>certainty; knowledge>chair; knowledge>content; knowledge>data; knowledge>debate; knowledge>description; knowledge>education; knowledge>evidence; knowledge>experience; knowledge>experiment; knowledge>fact; knowledge>geography; knowledge>history; knowledge>information; knowledge>inquiry; knowledge>intelligence; knowledge>intensity; knowledge>learning; knowledge>measurement; knowledge>narrative; knowledge>observation; knowledge>perception; knowledge>philosopher; knowledge>philosophy; knowledge>reasoning; knowledge>science; knowledge>space; knowledge>truth; knowledge>wisdom; knuckle>finger; knuckle>list; knuckle>hand; knuckle>joint; lab>laboratory; label>banana; label>black; label>cloth; label>image; label>ink; label>metal; label>paper; label>plastic; label>recycling; label>retail; label>sandwich; label>sewing; label>shirt; label>wine; laboratory>biology; laboratory>chemistry; laboratory>computer; laboratory>data; laboratory>emergency; laboratory>experiment; laboratory>explosive; laboratory>government; laboratory>industry; laboratory>laser; laboratory>machinery; laboratory>measurement; laboratory>physics; laboratory>poison; laboratory>psychology; laboratory>research; laboratory>safety; laboratory>school; laboratory>science; laboratory>scientist; laboratory>ship; laboratory>thermometer; laboratory>university; laboratory>workshop; labour>employment; labour>workforce; ladder>aluminium; ladder>bruise; ladder>honey; ladder>roof; ladder>rope; ladder>wall; ladder>wood; lady>woman; lake>acre; lake>bay; lake>climate; lake>continent; lake>crocodile; lake>density; lake>ecology; lake>erosion; lake>fish; lake>force; lake>friction; lake>geography; lake>industry; lake>inertial water; lake>pond; lake>recreation; lake>river; lake>salt; lake>sand; lake>stream; lake>temperature; lake>turkey; lake>volcano; lamb>sheep; land>country; land>earth; land>landscape; land>nation; landings>aircraft; landing>airport; landing>animal; landing>concrete; landing>flight; landing>parachute; landing>runway; landing>weather; landing>weight; landing>wind; landlady>landlord; landlord>apartment; landlord>contract; landlord>female; landlord>house; landlord>property; landmark>building; landmark>exploration; landmark>geography; landmark>monument; landmark>structure; landmark>tourist; landscape>beauty; landscape>coast; landscape>desert; landscape>earth; landscape>forest; landscape>geography; landscape>island; landscape>lake; landscape>lighting; landscape>mountain; landscape>perception; landscape>philosophy; landscape>river; landscape>sea; landscape>sky; landscape>theatre; landscape>weather; landscape>vegetation; lane>ambulance; lane>motorway; lane>road; lane>rush hour; lane>traffic light; language>adjective; language>argument; language>bee; language>code; language>communication; language>consonant; language>culture; language>dialect; language>entertainment; language>evolution; language>first language; language>globalization; language>grammar; language>human; language>idiom; language>information; language>mind; language>music; language>noun; language>phrase; language>prefix; language>speech; language>suffix; language>syllable; language>system; language>verb; language>vocabulary; language>word; language>vowel; lap>computer; lap>knee; lap>laptop; laptop>cd-rom; laptop>computer; laptop>floor; laptop>hard drive; laptop>theft;

marketing>business; marketing>manufacturing; marketing>organization; marriage>community; marriage>contract; marriage>divorce; marriage>economics; marriage>emotion; marriage>family; marriage>fear; marriage>gender; marriage>human rights; marriage>husband; marriage>hypothesis; marriage>institution; marriage>mother; marriage>organization; marriage>parent; marriage>prejudice; marriage>priest; marriage>promise; marriage>referendum; marriage>right; marriage>sin; marriage>spouse; marriage>suicide; marriage>tribe; marriage>turkey; marriage>wedding; marriage>wife; marriage>vocation; mask>ballet; mask>baseball; mask>brass; mask>carnival; mask>cartoon; mask>ceremony; mask>community; mask>copper; mask>court; mask>devil; mask>disguise; mask>drama; mask>entertainment; mask>face; mask>folk; mask>god; mask>gold; mask>hero; mask>ice hockey; mask>leather; mask>museum; mask>performance; mask>procession; mask>prosecution; mask>protect; mask>ritual; mask>shield; mask>stadium; mask>theatre; mask>torture; mask>trophy; mask>tv; mask>witness; massacre>disaster; massacre>sack; master>miss; masterpiece>painting; mat>bacteria; mat>bark; mat>bathroom; mat>building; mat>car; mat>carpet; mat>coconut; mat>commerce; mat>disc jockey; mat>floor; mat>furniture; mat>greeting; mat>kitchen; mat>pain; mat>pollution; mat>rubber; mat>sport; mat>straw; mat>structure; mat>surface; mat>towel; mat>type; mat>water; mat>vehicle; match>aircraft; match>chemistry; match>fire; match>firework; match>friction; match>glass; match>gun; match>lead; match>lighter; match>monopoly; match>nickname; match>paper; match>rope; match>rubber; match>slang; match>sugar; match>tool; match>wood; material>building; material>clothing; material>computer; material>construction; material>cotton; material>manufacturing; material>matter; material>steel; materialism>consciousness; materialism>energy; materialism>existence; materialism>force; materialism>institution; materialism>matter; materialism>mind; materialism>philosophy; materialism>reality; materialism>materialism; matter>atom; matter>chemistry; matter>density; matter>earth; matter>energy; matter>fluid; matter>formula; matter>gas; matter>lightning; matter>liquid; matter>materialism; matter>physics; matter>pressure; matter>science; matter>science fiction; matter>space; matter>telescope; matter>temperature; matter>time; matter>water; matter>wave; matter>volume; may>autumn; may>drum; may>month; may>november; may>summer; may>sunday; may>turkey; may>week; may>year; mayor>magistrate; mayor>officer; mayor>parliament; mayor>prime minister; mayor>referendum; meal>beach; meal>beer; meal>birthday; meal>breakfast; meal>cheese; meal>dessert; meal>dinner; meal>fish; meal>food; meal>forest; meal>fruit; meal>home; meal>law; meal>lunch; meal>main course; meal>nutrition; meal>park; meal>picnic; meal>restaurant; meal>salad; meal>sandwich; meal>supper; meal>tea; meal>wedding; meaning>reference; meaning>truth; measure>measurement; measurement>carbon; measurement>commerce; measurement>day; measurement>fraud; measurement>gram; measurement>hour; measurement>inch; measurement>kilogram; measurement>kilometre; measurement>law; measurement>length; measurement>light; measurement>metre; measurement>mile; measurement>month; measurement>ruler; measurement>science; measurement>second; measurement>spectrum; measurement>statistics; measurement>technology; measurement>temperature; measurement>time; measurement>ton; measurement>uncertainty; measurement>week; measurement>yard; measurement>year; meat>agriculture; meat>antibiotic; meat>bacteria; meat>barbecue; meat>beef; meat>body; meat>breed; meat>camel; meat>carbon dioxide; meat>cattle; meat>chicken; meat>cholesterol; meat>cooking; meat>crocodile; meat>deer; meat>disease; meat>dolphin; meat>evolution; meat>fat; meat>fish; meat>food; meat>gene; meat>gun; meat>ham; meat>herb; meat>hygiene; meat>insect; meat>iron; meat>liver; meat>mammal; meat>muscle; meat>oak; meat>oxygen; meat>pain; meat>pork; meat>protein; meat>salt; meat>sandwich; meat>sausage; meat>sheep; meat>smoke; meat>spice; meat>species; meat>steak; meat>sugar; meat>supermarket; meat>wheat; meat>wood; meat>zebra; mechanic>air conditioning; mechanic>brake; mechanic>customer; mechanic>electricity; mechanic>engine; mechanic>tank; mechanic>technician; mechanism>machine; medal>brass; medal>bronze; medal>coal; medal>copper; medal>glass; medal>gold; medal>iron; medal>lead; medal>paper; medal>plastic; medal>portrait; medal>relief; medal>sculpture; medal>silver; medal>soldier; medal>tin; medal>wood; medicine>amateur; medicine>antibiotic; medicine>aspirin; medicine>biology; medicine>clinic; medicine>diagnosis; medicine>dilemma; medicine>disease; medicine>ear; medicine>engineering; medicine>error; medicine>evolution; medicine>gene; medicine>genetics; medicine>health; medicine>health care; medicine>heart; medicine>honesty; medicine>illness; medicine>immune system; medicine>laboratory; medicine>literature; medicine>medication; medicine>nurse; medicine>philosophy; medicine>physics; medicine>poison; medicine>professional; medicine>psychology; medicine>pulse; medicine>side effect; medicine>snake; medicine>surgery; medicine>therapy; medicine>translation; medicine>tribe; medicine>truth; medicine>vaccination; medicine>vaccine; medicine>virus; medicine>x-ray; melody>composer; melody>harmony; melody>jazz; melody>lyrics; melody>rhythm; melody>song; member>bridge; member>club; membership>member; memorial>cross; memorial>fountain; memorial>monument; memorial>scholarship; memorial>status; memorial>war; memory>knowledge; memory>learning; memory>phenomenon; memory>psychology; memory>recollection; memory>sleep; memory>university; mention>quote; menu>advertising; menu>chef; menu>fast food; menu>hospital; menu>restaurant; mercy>forgiveness; mercy>justice; message>communication; message>email; message>idea; message>information; message>language; message>mail; message>radio; message>television; message>thought; metal>acid; metal>aluminium; metal>art; metal>bronze; metal>carbon; metal>chemistry; metal>commodity; metal>copper; metal>crystal; metal>currency; metal>density; metal>electricity; metal>gold; metal>heat; metal>iron; metal>lead; metal>painting; metal>silver; metal>steel; metaphor>analogy; metaphor>anger; metaphor>cliché; metaphor>description; metre>atom; metre>brass; metre>centimetre; metre>earth; metre>inch; metre>kilogram; metre>kilometre; metre>length; metre>light; metre>millimetre; metre>red; metre>second; metre>sphere; metre>yard; microphone>aircraft; microphone>computer; microphone>concert; microphone>insect; microphone>police; microphone>pressure; microphone>radio; microphone>sound; microphone>telephone; microphone>television; midday>noon; midnight>day; midnight>noon; midnight>season; midnight>sunrise; midnight>sunset; mile>emperor; mile>kilometre; mile>length; mile>metre; mile>province; mile>street; mile>yard; milk>acid; milk>agriculture; milk>bacteria; milk>beef; milk>breast; milk>butter; milk>camel; milk>cattle; milk>cheese; milk>cow; milk>cream; milk>digestion; milk>food; milk>goat; milk>gram; milk>honey; milk>horse; milk>human; milk>ice cream; milk>infant; milk>mammal; milk>nutrition; milk>pint; milk>poverty; milk>protein; milk>sheep; milk>spinach; milk>supermarket; milk>turkey; milk>water; milk>vegetarian; milk>whale; milk>yogurt; millennium>analogy; millennium>calendar; millennium>century; millennium>decade; millimetre>inch; millimetre>length; millimetre>metre; mind>adaptation; mind>art; mind>artificial intelligence; mind>attention; mind>awareness; mind>biology; mind>body; mind>brain; mind>choice; mind>communication; mind>computer; mind>concept; mind>conscience; mind>consciousness; mind>conversation; mind>dialogue; mind>drama; mind>economics; mind>emotion; mind>empathy; mind>engineering; mind>evolution; mind>family; mind>fear; mind>feeling; mind>gene; mind>happiness; mind>hate; mind>human; mind>idea; mind>image; mind>imagination; mind>intelligence; mind>intention; mind>knowledge; mind>language; mind>learning; mind>life; mind>love; mind>machine; mind>materialism; mind>matter; mind>memory; mind>perception; mind>narrative; mind>philosopher; mind>philosophy; mind>pie; mind>psychology; mind>reality; mind>reason; mind>religion; mind>ritual; mind>science; mind>skull; mind>software; mind>soul; mind>spirit; mind>symbol; mind>taste; mind>therapist; mind>thought; mind>tool; mind>well-being; mind>video game; mind>yoga; mine>mining; miner>coal; miner>mining; mineral water>salt; mineral water>tourism; mining>agriculture; mining>aluminium; mining>coal; mining>commodity; mining>copper; mining>earth; mining>erosion; mining>factory; mining>geology; mining>gold; mining>laboratory; mining>lead; mining>metal; mining>silver; mining>tin; mining>tool; mining>tram; mining>weapon; mining>vein; minority>infancy; minority>majority; minority>population; minute>angle; minute>astronomy; minute>earth; minute>hour; minute>second; minute>time; miracle>coincidence; miracle>donkey; miracle>dream; miracle>earthquake; miracle>evidence; miracle>faith; miracle>god; miracle>history; miracle>philosophy; miracle>saint; miracle>science; mirror>angle; mirror>astronomy; mirror>candle; mirror>human; mirror>illusion; mirror>laser; mirror>mammal; mirror>mechanic; mirror>paint; mirror>photography; mirror>portrait; mirror>sphere; mirror>telescope; mirror>vase; mirror>x-ray; misery>pain; misery>suffering; misery>unhappiness; miss>mrs; miss>servant; missile>engine; missile>explosive; missile>gun; missile>heat; missile>laser; missile>radiation; mist>air; mist>fog; mist>water; mist>weather; misunderstanding>understanding; mix>mixture; mixture>air; mixture>blood; mixture>chemistry; mixture>cloud; mixture>concrete; mixture>dust; mixture>fog; mixture>gas; mixture>gold; mixture>ink; mixture>liquid; mixture>metal; mixture>milk; mixture>mist; mixture>mud; mixture>oxygen; mixture>plastic; mixture>silver; mixture>smoke; mixture>soil; mixture>solution; mixture>sugar; mixture>water; mobile phone>email; mobile>mobile phone; mode>fashion; model>role model; model>system; momentum>explosion; momentum>heat; momentum>kilogram; momentum>light; momentum>plural; momentum>pressure; momentum>rocket; momentum>second; momentum>sound; momentum>star; momentum>wave; monday>angel; monday>heaven; monday>saturday; monday>sunday; monday>thursday; monday>tuesday; money>art; money>bank; money>banking; money>cash; money>century; money>cheque; money>commodity; money>copper; money>country; money>currency; money>debt; money>diamond; money>economics; money>exchange rate; money>gold; money>government; money>inflation; money>liberty; money>loan; money>monopoly; money>payment; money>receipt; money>recession; money>rice; money>silver; money>stock; money>tax; money>unemployment; monkey>human; monkey>species; monopoly>canal; monopoly>company; monopoly>competition; monopoly>famine; monopoly>industry; monopoly>law; monopoly>market; monopoly>regulation; monster>cattle; monster>colour; monster>devil; monster>dinosaur; monster>energy; monster>eye; monster>fish; monster>forehead; monster>gene; monster>goat; monster>legend; monster>lion; monster>mouse; monster>oxygen; monster>planet; monster>siren; monster>skull; month>april; month>august; month>autumn; month>calendar; month>day; month>december; month>february; month>indination; month>january; month>july; month>june; month>march; month>may; month>november; month>october; month>rose; month>second; month>september; month>star; month>summer; month>sun; month>time; month>weekday; month>wine; month>winter; month>year; monument>archaeologist; monument>building; monument>column; monument>memorial; monument>pyramid; monument>statue; monument>temple; monument>tomb; moonlight>daylight; moonlight>earth; moonlight>sun; moonlight>sunlight; morale>comfort; morale>courtesy; morale>duty; morale>fear; morale>motivation; morale>self-discipline; morale>willpower; morning>afternoon; morning>analogy; morning>breakfast; morning>day; morning>evening; morning>game; morning>midnight; morning>newspaper; morning>night; morning>noon; morning>sunrise; mortality>death; mortality>human; mosque>cathedral; mosque>clinic; mosque>column; mosque>dawn; mosque>gym; mosque>hazard; mosque>image; mosque>library; mosque>protest; mosque>pyramid; mosque>sunrise; mosque>sunset; mosque>symbol; mosque>vandalism; mosquito>adult; mosquito>animal; mosquito>bacteria; mosquito>bat; mosquito>carbon dioxide; mosquito>dawn; mosquito>disease; mosquito>fly; mosquito>head; mosquito>human; mosquito>immune system; mosquito>insect; mosquito>predator; mosquito>protein; mosquito>salmon; mosquito>sugar; mosquito>virus; mother>child; mother>emperor; mother>father; mother>human; mother>immune system; mother>mammal; mother>milk; mother>nutrition; mother>pregnancy; mother>stepmother; mother>wife; mother>woman; motivation>acceptance; motivation>addiction; motivation>curiosity; motivation>economics; motivation>family; motivation>feedback; motivation>food; motivation>friendship; motivation>game; motivation>goal; motivation>health; motivation>hunger; motivation>independence; motivation>love; motivation>money; motivation>observation; motivation>philosophy; motivation>psychologist; motivation>psychology; motivation>punishment; motivation>responsibility; motivation>safety; motivation>salary; motivation>saving; motivation>security; motivation>self-esteem; motivation>threat; motivation>tranquility; motivation>water; motive>motivation; motor>engine; mountain>agriculture; mountain>earth; mountain>erosion; mountain>hill; mountain>hobby; mountain>human; mountain>ice; mountain>landscape; mountain>mining; mountain>ocean; mountain>profession; mountain>river; mountain>snow; mountain>sport; mountain>tourism; mountain>volcano; mouse>animal; mouse>biology; mouse>cat; mouse>disease; mouse>dog; mouse>earth; mouse>experiment; mouse>fox; mouse>game; mouse>generation; mouse>ink; mouse>mammal; mouse>paper; mouse>pet; mouse>protein; mouse>psychology; mouse>rat; mouse>reptile; mouse>snake; mouse>species; mouse>stache>beard; mouse>stache>chin; mouse>stache>comb; mouse>stache>lip; mouse>stache>pencil; mouse>stache>scissors; move>immigration; movie>film; mud>brick; mud>concrete; mud>construction; mud>frog; mud>pig; mud>sand; mud>soil; mud>sun; mud>water; mud>worm; mug>coffee; mug>fluid; mug>pottery; mug>saucer; mug>tea; mum>mother; murder>animal; murder>assault; murder>corporation; murder>drug; murder>law; murder>precedent; murder>prostitute; murder>rape; murder>sin; murder>suicide; murder>war; murderer>murder; muscles>ancestor; muscles>bone; muscles>brain; muscle>cancer; muscle>cycling; muscle>density; muscle>dna; muscle>energy; muscle>fat; muscle>heart; muscle>infant; muscle>jaw; muscle>jogging; muscle>mammal; muscle>marathon; muscle>meat; muscle>motion; muscle>nerve; muscle>oxygen; muscle>protein; muscle>sense; muscle>skeleton; muscle>stomach; muscle>tongue; museum>agriculture; museum>aircraft; museum>animal; museum>archaeology; museum>astronomy; museum>computer; museum>craft; museum>drawing; museum>geology; museum>glass; museum>history; museum>illustration; museum>invention; museum>library; museum>musician; museum>painting; museum>philosophy; museum>physics; museum>propaganda; museum>science; museum>sculpture; museum>tank; museum>technology; museum>weapon; museum>zoo; mushroom>anxiety; mushroom>cooking; mushroom>copper; mushroom>disease; mushroom>food; mushroom>immune system; mushroom>species; mushroom>wool; music>addiction; music>archaeology; music>art; music>artificial intelligence; music>ballet; music>basketball; music>choir; music>composer; music>computer; music>concert; music>cooperation; music>disc jockey; music>dissertation; music>emotion; music>entertainment; music>flute; music>globalization; music>guitar; music>harmony; music>intellect; music>jazz; music>language; music>lyrics; music>melody; music>memory; music>musician; music>opera; music>orchestra; music>performance; music>physics; music>piano; music>propaganda; music>psychology; music>radio; music>rhythm; music>singer; music>song; music>speech; music>structure; music>television; music>time; music>university; music>violin; musical>music; musician>chapel; musician>composer; musician>jazz; musician>melody; musician>music; musician>poetry; musician>profession; musician>revolution; musician>singer; musician>singing; musician>society; mystery>secret; name>astronomy; name>dolphin; name>god; name>nickname; name>peace; name>science; name>slavery; name>spirit; name>war; nap>insomnia; nap>midday; nap>sleep; narrative>animation; narrative>communication; narrative>culture; narrative>data; narrative>description; narrative>drama; narrative>fiction; narrative>film; narrative>legend; narrative>literature; narrative>narrator; narrative>novel; narrative>openness; narrative>photography; narrative>poem; narrative>poetry; narrative>report; narrative>self; narrative>song; narrative>speech; narrative>television; narrative>theatre; narrative>validity; narrative>video;

narrative>writing; nation>civilization; nation>community; nation>country; nation>culture; nation>government; nation>nationality; nation>society; nation>tribe; nationality>candidate; nationality>passport; nationality>politics; nationality>treaty; native speaker>first language; nature>adaptation; nature>air; nature>animal; nature>art; nature>atmosphere; nature>bacteria; nature>bay; nature>beauty; nature>biology; nature>bird; nature>bone; nature>civilization; nature>climate change; nature>cloud; nature>consciousness; nature>continent; nature>digestion; nature>dinosaur; nature>dna; nature>dust; nature>earth; nature>energy; nature>era; nature>evolution; nature>extinction; nature>fish; nature>fishing; nature>gas; nature>genetics; nature>geology; nature>habitat; nature>hill; nature>human; nature>hunting; nature>ice; nature>intrusion; nature>kilogram; nature>laboratory; nature>lake; nature>life; nature>lightning; nature>liquid; nature>mammal; nature>materialism; nature>matter; nature>mind; nature>mining; nature>mountain; nature>muscle; nature>observation; nature>ocean; nature>oxygen; nature>phenomenon; nature>photography; nature>physics; nature>planet; nature>plant; nature>poetry; nature>pollution; nature>pond; nature>recreation; nature>reproduction; nature>river; nature>science; nature>sea; nature>soil; nature>species; nature>star; nature>steam; nature>stream; nature>sun; nature>surface; nature>temperature; nature>tornado; nature>weather; nature>wilderness; nature>wildlife; nature>volcano; nature>zoo; navy>combat; navy>commander; navy>lake; navy>ocean; navy>port; navy>river; navy>soil; necessity>child; necessity>community; necessity>crime; necessity>law; necessity>organization; necessity>bronze; neck>adjective; neck>body; neck>chin; neck>jaw; neck>pain; neck>throat; necklace>bracelet; necklace>bronze; necklace>chain; necklace>copper; necklace>coral; necklace>cross; necklace>diamond; necklace>gold; necklace>jewellery; necklace>laser; necklace>love; necklace>neck; necklace>shark; necklace>silver; necklace>tooth; necklace>vine; need>education; need>life; need>philosophy; need>politics; need>respect; need>self-esteem; neglect>abuse; neglect>negligence; neglect>self-esteem; negligence>carelessness; negligence>contract; negligence>harm; negligence>insurance; negligence>neglect; negligence>railway; negligence>train; negotiation>anger; negotiation>compromise; negotiation>contract; negotiation>conversation; negotiation>dialogue; negotiation>diplomacy; negotiation>disappointment; negotiation>emotion; negotiation>laboratory; negotiation>leadership; negotiation>pride; negotiation>sadness; negotiation>worry; neighbourhood>city; neighbourhood>community; neighbourhood>district; neighbourhood>fence; neighbourhood>household; neighbourhood>law; neighbourhood>security; neighbourhood>suburb; neighbourhood>town; neighbourhood>turkey; neighbourhood>village; nerve>brain; nerve>muscle; nerve>pain; nerve>sense; nerve>skin; nerve>walking; nerves>nerve; nervousness>anxiety; nervousness>worry; nest>bird; nest>eagle; nest>fish; nest>grass; nest>habitat; nest>insect; nest>leaf; nest>life; nest>mammal; nest>reptile; nest>snake; nest>soil; nest>tree; nest>wasp; networking>network; news>consumer; news>information; news>mobile phone; news>opinion; news>radio; news>reporter; news>satellite; news>television; newsletter>club; newsletter>email; newsletter>interest; newsletter>marketing; newsletter>newspaper; newsletter>publication; newspaper>bias; newspaper>digital camera; newspaper>intellectual; newspaper>reporter; newspaper>weather forecast; nickname>ambiguity; nickname>ceremony; nickname>electician; nickname>father; nickname>generation; nickname>genius; nickname>glasses; nickname>grandfather; nickname>home; nickname>intelligence; nickname>psychology; nickname>sir; nickname>surgeon; night>animal; night>carbon dioxide; night>day; night>earth; night>economy; night>energy; night>fear; night>ghost; night>horizon; night>life; night>lighting; night>lightning; night>midnight; night>moonlight; night>nightclub; night>nightlife; night>planet; night>plant; night>police station; night>season; night>sleep; night>sun; night>time; night>water; nightclub>celebrity; nightclub>concert; nightclub>dance; nightclub>disc jockey; nightclub>disco; nightclub>drug; nightclub>nightlife; nightclub>techno; nightlifer>adult; nightlifer>concert; nightlifer>entertainment; nightlifer>murder; nightlifer>music; nightlifer>nightclub; nightlifer>party; nightlifer>restaurant; nightmare>anxiety; nightmare>brain; nightmare>dream; nightmare>fear; nightmare>fever; nightmare>harassment; nightmare>insomnia; nightmare>sadness; nightmare>sleep; nightmare>symptom; noise>data; noise>physics; noise>public transport; noise>radio; noise>silence; noise>sound; noise>television; noise>video; nomination>award; nomination>candidate; nomination>ceremony; nomination>debate; nomination>election; nomination>law; nomination>office; nonsense>contradiction; nonsense>grammar; nonsense>novelist; nonsense>poet; nonsense>poetry; nonsense>sense; nonsense>speech; nonsense>writing; noon>astronomy; noon>midnight; north>adjective; north>adverb; north>east; north>geography; north>map; north>noun; north>south; north>sun; north>west; north>west>southeast; nose>bat; nose>beak; nose>bird; nose>camel; nose>dog; nose>elephant; nose>mammal; nose>mouth; nose>nostril; nose>reptile; nostalgia>brain; nostalgia>happiness; nostalgia>music; nostalgia>sorrow; nostalgia>touch; nostril>bird; nostril>fish; nostril>human; nostril>mammal; nostril>nose; note>alphabet; note>music; note>musician; note>sound; notebook>drawing; notice>allegation; noun>adjective; noun>clause; noun>description; noun>determiner; noun>ear; noun>plural; noun>prefix; noun>preposition; noun>pronoun; noun>punctuation; noun>reference; noun>sense; noun>sex; noun>suffix; noun>verb; novel>adventure; novel>art; novel>bestseller; novel>child; novel>comic; novel>communication; novel>creativity; novel>dedication; novel>essay; novel>fantasy; novel>fiction; novel>gender; novel>globalization; novel>history; novel>individual; novel>industrialization; novel>invention; novel>joke; novel>literacy; novel>literature; novel>narrative; novel>newspaper; novel>psychology; novel>quest; novel>racism; novel>reality; novel>review; novel>science fiction; novel>sensibility; novel>virtual reality; novelist>novel; novelty>art; novelty>creativity; novelty>innovation; novelty>marketing; november>autumn; november>day; november>february; november>homelessness; november>january; november>march; november>may; november>month; november>saturday; november>sunday; november>war; november>winter; november>year; nuisance>agriculture; nuisance>contempt; nuisance>law; number>addition; number>stop; number>measurement; number>pyramid; number>rectangle; number>uncountable; nutrition>agriculture; nutrition>atmosphere; nutrition>berry; nutrition>blood; nutrition>bread; nutrition>butter; nutrition>cancer; nutrition>carbon; nutrition>cereal; nutrition>cheese; nutrition>chemical; nutrition>cholesterol; nutrition>confusion; nutrition>cooking; nutrition>copper; nutrition>diet; nutrition>digestion; nutrition>dna; nutrition>drought; nutrition>energy; nutrition>exercise; nutrition>experiment; nutrition>fast food; nutrition>fat; nutrition>flower; nutrition>food; nutrition>fruit; nutrition>garlic; nutrition>genetics; nutrition>grain; nutrition>grape; nutrition>herb; nutrition>human; nutrition>immune system; nutrition>iron; nutrition>junk food; nutrition>leaf; nutrition>life; nutrition>marathon; nutrition>meat; nutrition>metal; nutrition>milk; nutrition>obesity; nutrition>onion; nutrition>oxygen; nutrition>pasta; nutrition>potato; nutrition>protein; nutrition>psychology; nutrition>pump; nutrition>rice; nutrition>root; nutrition>science; nutrition>seed; nutrition>soil; nutrition>spice; nutrition>starvation; nutrition>sugar; nutrition>sunlight; nutrition>tea; nutrition>teaching; nutrition>technology; nutrition>water; nutrition>vegetable; nutrition>wheat; nutrition>wine; nutrition>vitamin; oak>bark; oak>butterfly; oak>cattle; oak>cheese; oak>commander; oak>endurance; oak>euro; oak>flower; oak>fruit; oak>furniture; oak>goat; oak>leaf; oak>leather; oak>plant; oak>sheep; oak>ship; oak>species; oak>symbol; oak>tree; oak>wine; oak>virtue; oak>wood; obesity>appetite; obesity>cancer; obesity>famine; obesity>gene; obesity>globalization; obesity>junk food; obesity>medication; obesity>pregnancy; obesity>stroke; object>entity; object>goal; obligation>politics; obligation>tradition; observation>camera; observation>clock; observation>data; observation>equal; observation>experiment; observation>human; observation>hypothesis; observation>information; observation>knowledge; observation>measurement; observation>nature; observation>paradox; observation>phenomenon; observation>sense; observation>system; observation>taste; observation>telescope; observation>thermometer; observation>x-ray; observer>observation; obstacle>architecture; obstacle>basketball; obstacle>cycling; obstacle>electricity; obstacle>football; obstacle>idiom; obstacle>infrastructure; obstacle>majority; obstacle>parliament; obstacle>public transport; obstacle>skill; obstacle>tennis; obstacle>volleyball; occupation>career; occupation>employment; occupation>profession; occupation>vocation; ocean>animal; ocean>bay; ocean>climate; ocean>coast; ocean>continent; ocean>dolphin; ocean>earth; ocean>evolution; ocean>fish; ocean>global warming; ocean>habitat; ocean>ice; ocean>life; ocean>planet; ocean>plant; ocean>rain; ocean>sea; ocean>ship; ocean>species; ocean>water; ocean>weather; ocean>whale; ocean>wind; october>april; october>autumn; october>blindness; october>day; october>health; october>lung; october>month; october>pizza; october>republic; october>sausage; october>turkey; october>year; odds>gambling; odds>probability; odds>proposition; odds>ratio; odds>statistics; office>adjective; office>building; office>business; office>desk; office>employment; office>factory; office>fashion; office>library; office>official; office>organization; office>project; office>software; office>warehouse; office>authority; officer>police officer; official>adjective; official>authority; official>bureaucracy; official>ceremony; official>election; official>employment; official>government; official>inheritance; official>jargon; official>noun; official>office; official>organization; official>referee; official>school; official>signpost; official>title; official>war; offspring>adult; offspring>biology; offspring>child; offspring>daughter; offspring>frog; offspring>parent; offspring>reproduction; offspring>son; oil>bit; oil>carbon; oil>heat; oil>light; oil>liquid; oil>oxygen; oil>protein; oil>ton; olive>drought; olive>flower; olive>frost; olive>fruit; olive>garlic; olive>herb; olive>leaf; olive>lemon; olive>rabbit; olive>root; olive>soil; olive>species; olive>spice; olive>ton; olive>tree; olive>turkey; olive>umbrella; olive>weed; olive>vine; olive>wine; olive>winter; omelette>beef; omelette>butter; omelette>cheese; omelette>cholesterol; omelette>cream; omelette>fat; omelette>frying pan; omelette>garlic; omelette>ham; omelette>leek; omelette>lung; omelette>meat; omelette>milk; omelette>onion; omelette>pasta; omelette>pea; omelette>pork; omelette>potato; omelette>salt; omelette>tomato; omelette>vegetable; omission>argument; omission>lie; onion>bean; onion>carrot; onion>cattle; onion>cheese; onion>dog; onion>economist; onion>fat; onion>garlic; onion>gene; onion>spice; onion>vegetable; onion>vinegar; openness>community; opera>carival; opera>costume; opera>drama; opera>musician; opera>orchestra; opera>singing; opera>tradition; opera>tragedy; operation>surgery; opinion>argument; opinion>belief; opinion>business; opinion>committee; opinion>economics; opinion>emotion; opinion>fact; opinion>jury; opinion>knowledge; opinion>philosophy; opinion>psychology; opinion>understanding; opportunity>crisis; opposite>volleyball; optimism>cancer; optimism>evolution; optimism>health; optimism>idiom; optimism>intelligence; optimism>philosophy; optimism>psychology; optimism>stroke; optimist>optimism; orchestra>ballet; orchestra>cello; orchestra>choir; orchestra>committee; orchestra>composer; orchestra>court; orchestra>dancing; orchestra>flute; orchestra>melody; orchestra>musician; orchestra>opera; orchestra>piano; orchestra>trumpet; orchestra>violin; ordeal>cruelty; ordeal>difficulty; ordeal>problem; ordeal>suffering; ordeal>torture; order>sequence; organ>magazine; organ>newsletter; organization>bureaucracy; organization>committee; organization>communication; organization>competition; organization>corporation; organization>ecology; organization>economics; organization>entity; organization>goal; organization>government; organization>human; organization>jury; organization>leadership; organization>management; organization>parliament; organization>partnership; organization>psychology; organization>pyramid; organization>structure; organization>university; origin>ancestor; origin>birth; origin>river; origin>time; ornament>fashion; orphan>adoption; orphan>suicide; outbreak>disease; output>computer; output>data; output>economics; output>engineering; output>feedback; output>information; output>sequence; output>system; oven>bread; oven>brick; oven>cake; oven>casserole; oven>coal; oven>computer; oven>concrete; oven>cooking; oven>dessert; oven>electricity; oven>heating; oven>meat; oven>pizza; oven>pottery; oven>steel; overdraft>adverb; overdraft>bank; overdraft>contract; overdraft>debit; overdraft>interest; overdraft>preposition; owl>adaptation; owl>beak; owl>bird; owl>dawn; owl>dinosaur; owl>ecology; owl>feather; owl>fish; owl>mammal; owl>species; owl>traffic; owl>wisdom; owner>ownership; ownership>asset; ownership>body; ownership>building; ownership>business; ownership>capitalism; ownership>consideration; ownership>controversy; ownership>debt; ownership>exchange; ownership>gift; ownership>idea; ownership>individual; ownership>innovation; ownership>invention; ownership>law; ownership>manufacturing; ownership>mind; ownership>money; ownership>person; ownership>property; ownership>slavery; ownership>theft; ownership>trade; oxygen>acid; oxygen>alcohol; oxygen>aluminium; oxygen>bacteria; oxygen>barbecue; oxygen>carbon; oxygen>carbon dioxide; oxygen>carbon monoxide; oxygen>centimetre; oxygen>climate change; oxygen>detective; oxygen>disease; oxygen>dna; oxygen>earth; oxygen>explosion; oxygen>extinction; oxygen>fabric; oxygen>fat; oxygen>fire; oxygen>fuel; oxygen>gas; oxygen>immune system; oxygen>iron; oxygen>litre; oxygen>medicine; oxygen>ozone; oxygen>plastic; oxygen>protein; oxygen>rocket; oxygen>sand; oxygen>skeleton; oxygen>smog; oxygen>spider; oxygen>sport; oxygen>star; oxygen>steel; oxygen>sun; oxygen>tin; oxygen>water; oxygen>vein; oxygen>wood; ozone>aluminium; ozone>atom; ozone>carbon; ozone>carbon dioxide; ozone>climate change; ozone>concentration; ozone>earth; ozone>electricity; ozone>fruit; ozone>glass; ozone>gold; ozone>heart attack; ozone>immune system; ozone>iron; ozone>lead; ozone>lightning; ozone>liquid; ozone>mining; ozone>open; ozone>paper; ozone>salt; ozone>silver; ozone>water; ozone>vegetable; pace>peace; pack>backpack; pack>surname; pact>contract; pact>treaty; page>web page; pain>anxiety; pain>cancer; pain>medication; pain>suffering; pain>toothache; pain>torture; paint>alcohol; paint>bacteria; paint>brush; paint>ink; paint>lead; paint>liquid; paint>milk; paint>oxygen; paint>sunshine; painter>painting; painting>artist; painting>beauty; painting>brush; painting>concept; painting>copper; painting>craft; painting>design; painting>drawing; painting>essay; painting>face; painting>film; painting>glass; painting>illustration; painting>language; painting>leaf; painting>leather; painting>literature; painting>logo; painting>music; painting>nature; painting>oil; painting>paint; painting>paper; painting>pen; painting>philosophy; painting>photograph; painting>photography; painting>poetry; painting>politics; painting>portrait; painting>red; painting>rhythm; painting>sand; painting>solution; painting>straw; painting>surface; painting>symbol; painting>truth; painting>wall; painting>weather; painting>wood; painting>writing; pair>air; pair>cricket; pair>pear; pair>pressure; palace>castle; palace>chapel; palace>coconut; palace>hotel; palace>mansion; palace>museum; palace>parliament; palace>warehouse; pan>frying pan; pan>pancake; pan>prefix; pan>review; pancake>bacon; pancake>banana; pancake>breakfast; pancake>butter; pancake>cake; pancake>curry; pancake>fruit; pancake>frying pan; pancake>honey; pancake>jam; pancake>rice; pancake>synonym; pancake>yogurt; panel>jury; panic>anxiety; panic>architect; panic>cliff; panic>design; panic>emotion; panic>fear; panic>human; panic>marathon; panic>planning; panic>reason; panic>simulation; panic>symptom; pants>trousers; paper>art; paper>book; paper>cheque; paper>communication; paper>craft; paper>density; paper>diary; paper>drawing; paper>envelope; paper>grass; paper>handkerchief; paper>magazine; paper>newspaper; paper>notebook; paper>security; paper>straw; paper>wood; paper>writing; parachute>back; parachute>backpack; parachute>balloon; parachute>fair; parachute>landing; parachute>linen; parachute>probability; parachute>silk; parachute>weight; parade>carnival; parade>costume; parade>procession; parade>protest; paradigm>concept; paradigm>grammar; paradigm>photography; paradigm>physics; paradigm>science; paradigm>time; paradise>civilization; paradise>court; paradise>destiny; paradise>evil; paradise>evolution; paradise>garden; paradise>god; paradise>happiness; paradise>heaven; paradise>hell; paradise>park; paradise>peace; paradise>prosperity;

paradise>space; paradise>time; paradise>yard; paradox>common sense; paradox>contradiction; paradox>dilemma; paradox>irony; paradox>language; paradox>logic; paradox>philosopher; paradox>surgery; paradox>validity; paragraph>email; paragraph>idea; paragraph>initial; paragraph>writing; parallel>astronomy; parcel>mail; parent>adjective; parent>adoption; parent>ancestor; parent>bird; parent>birth; parent>child; parent>family; parent>father; parent>gene; parent>generation; parent>infant; parent>male; parent>mother; parent>offspring; parent>pregnancy; parent>protein; parent>reproduction; parent>sibling; parent>verb; park>car park; park>government; park>grass; park>insect; park>landscape; park>mansion; park>picnic; park>playground; park>recreation; park>shade; park>turkey; park>woodland; parking>board game; parking>fee; parking>house; parking>road; parking>vehicle; parliament>appeal; parliament>citizen; parliament>democracy; parliament>finance; parliament>government; parliament>justice; parliament>legislation; parliament>prime minister; parliament>tax; parrot>animal; parrot>bacteria; parrot>beak; parrot>bird; parrot>competition; parrot>dinosaur; parrot>evolution; parrot>flower; parrot>food; parrot>fruit; parrot>hunting; parrot>pet; parrot>poison; parrot>predator; parrot>fruit; parrot>seed; parrot>species; parrot>tongue; part>manufacturer; particle>atom; particle>beach; particle>carbon dioxide; particle>crowd; particle>dust; particle>friction; particle>gas; particle>liquid; particle>matter; particle>nature; particle>people; particle>sand; particle>sphere; particle>star; particle>structure; particle>volume; partner>friend; partner>husband; partner>partnership; partner>wife; partnership>alliance; partnership>contract; partnership>corporation; partnership>corruption; partnership>education; partnership>entity; partnership>government; partnership>interest; partnership>monopoly; partnership>organization; partnership>school; party>anniversary; party>balloon; party>banana; party>birthday; party>business; party>cake; party>conversation; party>dancing; party>dessert; party>dinner; party>disc jockey; party>disco; party>drink; party>election; party>film; party>food; party>friendship; party>hospitality; party>main course; party>mask; party>music; party>noise; party>opera; party>recreation; party>restaurant; party>sandwich; party>school; party>swimming pool; party>tea; party>techno; party>wedding; party>wine; passage>cave; passenger>bus; passenger>railway; passenger>ship; passenger>vehicle; passport>diplomacy; passport>government; passport>nationality; passport>receipt; passport>refugee; passport>travel; passport>treaty; password>backup; password>face; password>graphics; password>image; password>memory; password>mobile phone; password>word; pasta>cereal; pasta>chef; pasta>cholesterol; pasta>cooking; pasta>export; pasta>flour; pasta>ham; pasta>machine; pasta>sausage; pastime>hobby; pastry>bakery; pastry>biscuit; pastry>bread; pastry>butter; pastry>chocolate; pastry>cream; pastry>flour; pastry>milk; pastry>pasta; pastry>pie; pastry>sugar; patch>garden; patience>envy; patience>humility; patience>insect; patience>kindness; patience>pride; patience>time; patient>clinic; patient>dignity; patient>health care; patient>hospital; patient>human rights; patient>illness; patient>medication; patient>surgeon; patient>therapy; patient>treatment; pattern>carpet; pattern>column; pattern>crack; pattern>crystal; pattern>drawing; pattern>painting; pattern>physics; pattern>pineapple; pattern>reflection; pattern>tree; pattern>wave; pause>leisure; paw>bear; paw>cat; paw>dog; paw>fox; paw>friction; paw>mammal; paw>rabbit; paw>tiger; paw>toe; pay>payment; pay>salary; pay>wage; payment>business; payment>cash; payment>cheque; payment>coin; payment>commerce; payment>credit card; payment>debit card; payment>money; payment>receipt; payment>stock; payment>trade; pc>postcard; pc>weather forecast; pea>bean; pea>butter; pea>climate; pea>famine; pea>fruit; pea>genetics; pea>noun; pea>plant; pea>plural; pea>protein; pea>salt; pea>seed; pea>snack; pea>soup; pea>tree; pea>turkey; pea>vegetable; pea>vine; pea>vitamin; pea>aggression; pea>cooperation; pea>diplomacy; pea>economics; pea>geography; pea>history; pea>hostility; pea>knowledge; pea>psychology; pea>respect; pea>silence; pea>strategy; pea>tranquility; pea>war; pea>violence; peach>acid; peach>cherry; peach>flower; peach>leaf; peach>leather; peach>plant; peach>protein; peach>tree; peach>rush hour; peach>summit; peanut>beef; peanut>bird; peanut>cancer; peanut>cholesterol; peanut>cookie; peanut>cotton; peanut>flower; peanut>flower; peanut>fruit; peanut>juice; peanut>plant; peanut>plastic; peanut>rabbit; peanut>seed; peanut>spinach; pear>apple; pear>banana; pear>family; pear>flower; pear>furniture; pear>jam; pear>juice; pear>leaf; pear>olive; pear>plant; pear>rice; pear>species; pear>tobacco; pear>winter; pear>wood; peasant>farmer; peasant>literacy; peasant>slavery; pedestrian>obesity; pedestrian>public transport; pedestrian>road; pedestrian>running; pedestrian>traffic; pedestrian>trail; pedestrian>walking; pedestrian>vehicle; pedestrian>wheelchair; peer pressure>adolescent; peer pressure>alcohol; peer pressure>leadership; peer pressure>meeting; peer pressure>presentation; peer pressure>risk; peer pressure>tobacco; pen>ball; pen>brass; pen>drawing; pen>illustration; pen>ink; pen>inventor; pen>paper; pen>pencil; pen>status symbol; pen>steel; pen>writing; penalty>punishment; penalty>tax; pence>penny; pencil>chemistry; pencil>drawing; pencil>lead; pencil>leather; pencil>pen; pencil>ruler; pencil>wood; pencil>writing; penguin>animal; penguin>evolution; penguin>fish; penguin>habitat; penguin>iceberg; penguin>species; penguin>tail; penguin>wing; penny>commodity; penny>devil; penny>dollar; penny>euro; penny>silver; pension>asset; pension>government; pension>insurance; pension>investment; pension>lottery; pension>pensioner; pension>retirement; pension>stock; pension>tax; pensioner>pension; pensioner>retirement; pensioner>student; people>citizen; people>nation; people>nationality; people>person; people>republic; people>socialism; people>tribe; percentage>concentration; percentage>ratio; percentage>road; perception>brain; perception>ear; perception>ecology; perception>food; perception>hypothesis; perception>illusion; perception>information; perception>learning; perception>memory; perception>motivation; perception>paradigm; perception>psychology; perception>science; perception>sense; perception>simulation; perception>sound; perception>taste; perception>tongue; perfection>architect; perfection>architecture; perfection>art; perfection>artist; perfection>beauty; perfection>biology; perfection>chemistry; perfection>circle; perfection>civilization; perfection>concept; perfection>cooperation; perfection>creativity; perfection>crystal; perfection>education; perfection>existence; perfection>formula; perfection>god; perfection>grammar; perfection>harmony; perfection>health; perfection>heaven; perfection>idea; perfection>intellect; perfection>literature; perfection>matter; perfection>medicine; perfection>nature; perfection>number; perfection>painting; perfection>paradise; perfection>paradox; perfection>philosopher; perfection>philosophy; perfection>physics; perfection>plural; perfection>poet; perfection>poetry; perfection>praver; perfection>ratio; perfection>reason; perfection>religion; perfection>science; perfection>sculpture; perfection>shape; perfection>side; perfection>skill; perfection>society; perfection>sphere; perfection>spirit; perfection>structure; perfection>sum; perfection>superlative; perfection>technology; perfection>temple; perfection>virtue; performance>actor; performance>audience; performance>ballet; performance>baseball; performance>comedian; performance>concert; performance>dance; performance>music; performance>opera; performance>rehearsal; performance>singing; performance>theatre; perfume>aluminium; perfume>apple; perfume>bark; perfume>bulb; perfume>chemistry; perfume>cherry; perfume>cola; perfume>corporation; perfume>dirty; perfume>flower; perfume>fruit; perfume>heat; perfume>herb; perfume>honey; perfume>leaf; perfume>lemon; perfume>light; perfume>make-up; perfume>oxygen; perfume>pine; perfume>plant; perfume>root; perfume>rose; perfume>science; perfume>seed; perfume>shampoo; perfume>spice; perfume>strawberry; perfume>tobacco; perfume>tomato; perfume>trade; perfume>wood; period>full stop; person>abortion; person>consciousness; person>estate; person>human; person>individual; person>law; person>liberty; person>nation; person>people; person>philosophy; person>slavery; person>family; person>self; person>employment; person>advertising; persuasion>belief; persuasion>communication; persuasion>deception; persuasion>faith; persuasion>imagination; persuasion>intention; persuasion>logic; persuasion>motivation; persuasion>pity; persuasion>presentation; persuasion>propaganda; persuasion>torture; persuasion>tradition; pet>animal; pet>ant; pet>bird; pet>cat; pet>chocolate; pet>crab; pet>crocodile; pet>deer; pet>dog; pet>feather; pet>frog; pet>fur; pet>goat; pet>horse; pet>leopard; pet>lion; pet>monkey; pet>parrot; pet>rabbit; pet>sheep; pet>snake; pet>spider; pet>tiger; pharmacist>biology; pharmacist>chemist; pharmacist>chemistry; pharmacist>disease; pharmacist>economics; pharmacist>health; pharmacist>health care; pharmacist>medication; pharmacist>nutrition; pharmacist>patient; pharmacist>pharmacy; pharmacist>physics; pharmacist>wage; pharmacy>chemistry; pharmacy>clinic; pharmacy>copper; pharmacy>health; pharmacy>health care; pharmacy>hospital; pharmacy>lead; pharmacy>magazine; pharmacy>medication; pharmacy>nutrition; pharmacy>partnership; pharmacy>pharmacist; pharmacy>retailer; pharmacy>shampoo; pharmacy>supermarket; pharmacy>surgery; pharmacy>symbol; phenomenon>energy; phenomenon>experience; phenomenon>matter; phenomenon>observation; phenomenon>occurrence; phenomenon>philosophy; phenomenon>physics; phenomenon>theory; philosopher>argument; philosopher>concept; philosopher>human; philosopher>knowledge; philosopher>logic; philosopher>person; philosopher>philosophy; philosopher>proposition; philosopher>society; philosophy>argument; philosophy>art; philosophy>beauty; philosophy>belief; philosophy>body; philosophy>debate; philosophy>democracy; philosophy>dialogue; philosophy>economics; philosophy>essence; philosophy>existence; philosophy>faith; philosophy>god; philosophy>government; philosophy>health; philosophy>humility; philosophy>hypothesis; philosophy>integrity; philosophy>justice; philosophy>language; philosophy>law; philosophy>literature; philosophy>logic; philosophy>longevity; philosophy>lyrics; philosophy>materialism; philosophy>mind; philosophy>music; philosophy>nature; philosophy>number; philosophy>proposition; philosophy>proverb; philosophy>psychology; philosophy>reality; philosophy>reason; philosophy>reasoning; philosophy>theory; philosophy>time; philosophy>truth; philosophy>validity; philosophy>world; philosophy>yoga; phone>telephone; photo>photograph; photograph>acid; photograph>camera; photograph>dust; photograph>image; photograph>light; photograph>photography; photographer>advertising; photographer>amateur; photographer>landscape; photographer>photography; photographer>portrait; photograph>art; photograph>beauty; photograph>camera; photograph>computer; photograph>digital camera; photograph>gain; photograph>hobby; photograph>image; photograph>light; photograph>photocopy; photograph>photograph; photograph>photographer; photograph>professional; photograph>science; photograph>television; photograph>thermometer; photograph>tourism; photograph>video; phrasal verb>cliché; phrasal verb>collocation; phrasal verb>idiom; phrasal verb>particle; phrasal verb>phrase; phrasal verb>preposition; phrasal verb>verb; phrase>clause; phrase>word; physics>archaeology; physics>astronomy; physics>atom; physics>biology; physics>bridge; physics>chemistry; physics>computer; physics>curriculum; physics>earth; physics>electricity; physics>energy; physics>engineering; physics>experiment; physics>film; physics>force; physics>geology; physics>heat; physics>industrialization; physics>light; physics>lightning; physics>liquid; physics>matter; physics>nature; physics>phenomenon; physics>philosophy; physics>prediction; physics>research; physics>science; physics>society; physics>sound; physics>space; physics>technology; physics>television; physics>temperature; physics>theory; physics>time; physics>uncertainty; physics>water; physics>video game; piano>cd; piano>clutch; piano>composer; piano>jazz; piano>mp3 player; piano>performance; piano>rehearsal; piano>steel; piano>television; picnic>barbecue; picnic>earth; picnic>meal; picnic>rush hour; picnic>singer; picnic>soft drink; picture>image; pie>army; pie>basket; pie>beef; pie>biscuit; pie>box; pie>bread; pie>butcher; pie>cake; pie>chicken; pie>flour; pie>horse; pie>ice cream; pie>loaf; pie>mushroom; pie>pastry; pie>pizza; pie>pottery; pie>sea; pie>steak; pie>vegetable; pie>wheat; piece>coin; piece>sandwich; piece>unit; pig>animal; pig>art; pig>bacon; pig>extinction; pig>hair; pig>hunting; pig>idiom; pig>leather; pig>literature; pig>mammal; pig>metaphor; pig>pork; pig>religion; pig>tooth; pillow>back; pillow>bed; pillow>chair; pillow>cloth; pillow>cotton; pillow>cushion; pillow>dust; pillow>duvet; pillow>feather; pillow>knee; pillow>laundry; pillow>neck; pillow>silks; pillow>sleep; pillow>television; pin>brass; pin>copper; pin>plastic; pin>steel; pin>wire; pine>bark; pine>bat; pine>bird; pine>butterfly; pine>desert; pine>garden; pine>goat; pine>leaf; pine>park; pine>plant; pine>seed; pine>soil; pine>species; pine>tea; pine>timber; pine>tree; pineapple>bat; pineapple>cancer; pineapple>cherry; pineapple>digestion; pink>advertising; pink>aluminium; pink>beauty; pink>blue; pink>cartoon; pink>clothing; pink>corporation; pink>dawn; pink>girl; pink>globalization; pink>green; pink>hat; pink>health; pink>innocence; pink>love; pink>newspaper; pink>people; pink>pig; pink>prosecution; pink>purple; pink>red; pink>scarf; pink>slang; pink>socialism; pink>solicitor; pink>species; pink>sunset; pink>sweatshirt; pink>toy; pink>verb; pink>vest; pink>white; pink>yellow; pink>yoga; pint>beer; pint>cereal; pint>litre; pint>volume; pitch>tent; pity>aid; pity>emotion; pity>empathy; pity>mercy; pity>money; pity>self-esteem; pity>sorrow; pity>sympathy; pizza>bacon; pizza>banana; pizza>beef; pizza>bread; pizza>business; pizza>cabbage; pizza>champagne; pizza>cheese; pizza>chicken; pizza>corn; pizza>fast food; pizza>garlic; pizza>ham; pizza>honey; pizza>immigrant; pizza>lettuce; pizza>meat; pizza>mushroom; pizza>olive; pizza>onion; pizza>oven; pizza>pineapple; pizza>pork; pizza>salad; pizza>salt; pizza>sausage; pizza>spinach; pizza>tomato; pizza>ton; pizza>tuna; pizza>vegetable; place>gambling; place>mansion; place>business; place>career; place>combat; place>communication; place>corporation; place>diplomacy; place>engineer; place>goal; place>government; place>individual; place>legislation; place>logic; place>map; place>mind; place>planning; place>project; place>psychology; place>regulation; place>science; place>set; place>space; place>strategy; planet>astronomy; planet>atmosphere; planet>carbon dioxide; planet>common sense; planet>day; planet>earth; planet>fluid; planet>gas; planet>history; planet>inclination; planet>iron; planet>life; planet>oxygen; planet>population; planet>pressure; planet>religion; planet>science; planet>sear; planet>space; planet>star; planet>sun; planet>telescope; planet>water; planet>volcano; planet>year; planning>intelligence; planning>management; planning>plan; plant>agriculture; plant>alcohol; plant>ant; plant>aspirin; plant>bacteria; plant>beer; plant>branch; plant>carbon dioxide; plant>cereal; plant>coal; plant>coffee; plant>cotton; plant>crop; plant>erosion; plant>extinction; plant>flower; plant>forest; plant>frost; plant>fruit; plant>garden; plant>gardening; plant>grain; plant>grass; plant>herb; plant>leaf; plant>life; plant>light; plant>mushroom; plant>oak; plant>olive; plant>oxygen; plant>population; plant>potato; plant>rainforest; plant>rice; plant>rod; plant>smoking; plant>soil; plant>species; plant>spice; plant>sugar; plant>sunlight; plant>tea; plant>temperature; plant>timber; plant>tobacco; plant>tree; plant>water; plant>weed; plant>vegetable; plant>wheat; plant>wine; plant>wood; plastic>alcohol; plastic>bone; plastic>carbon; plastic>chewing gum; plastic>copper; plastic>density; plastic>film; plastic>glass; plastic>global warming; plastic>leather; plastic>metal; plastic>oxygen; plastic>paper; plastic>rubber; plastic>silks; plastic>stocking; plastic>wood; player>cd player; playground>business; playground>child; playground>enjoyment; playground>metaphor; playground>park; playground>president; playground>recreation; playground>rocket; playground>school; playground>sport; plea>crime; plea>trial; pleasure>art; pleasure>enjoyment; pleasure>entertainment; pleasure>exercise; pleasure>happiness; pleasure>intellectual; pleasure>leisure; pleasure>literature; pleasure>music; pleasure>pain; pleasure>pride; pleasure>psychology; pleasure>sense; pleasure>suffering; plot>grave; plumber>lead; plumber>metaphor; plumber>water; plural>adjective; plural>noun; plural>pronoun; plural>verb; pocket>backpack; pocket>bag; pocket>clothing; pocket>envelope; pocket>jeans; pocket>luggage; pocket>trousers; pocket>wheat; poem>poetry; poet>poetry; poet>writer; poetry>ambiguity; poetry>comedy; poetry>culture; poetry>dialect; poetry>drama; poetry>feeling; poetry>funeral; poetry>globalization; poetry>grammar;

poetry>irony; poetry>language; poetry>literacy; poetry>literature; poetry>memory; poetry>metaphor; poetry>music; poetry>narrative; poetry>paragraph; poetry>perception; poetry>person; poetry>rhyme; poetry>rhythm; poetry>science fiction; poetry>song; poetry>symbol; poetry>tragedy; poetry>translation; points>full stop; points>inch; points>prize; poison>bacteria; poison>biology; poison>bite; poison>carbon monoxide; poison>heart; poison>human; poison>iron; poison>lead; poison>liver; poison>medication; poison>medicine; poison>murder; poison>pain; poison>physics; poison>protein; poison>suicide; polar bear>animal; polar bear>bacteria; polar bear>bear; polar bear>berry; polar bear>climate change; polar bear>crab; polar bear>dna; polar bear>evolution; polar bear>fish; polar bear>liver; polar bear>mammal; polar bear>meat; polar bear>plastic; polar bear>pollution; polar bear>root; polar bear>sea; polar bear>waste; polar bear>whale; polar bear>wolf; pole>column; pole>spouse; pole>tree; police officer>arrest; police officer>bribe; police officer>crime; police officer>criminal; police officer>detective; police officer>fraud; police officer>inspector; police officer>murder; police officer>police; police officer>racism; police officer>rape; police officer>salary; police officer>traffic; police station>building; police station>inspector; police station>police officer; police station>suburb; police>arrest; police>bicycle; police>crime; police>detective; police>fraud; police>jury; police>law; police>police officer; police>population; police>pork; police>prostitute; police>racism; police>radio; police>torture; police>traffic; police>uniform; police>whistle; policeman>police officer; policewoman>police officer; policy>artificial intelligence; policy>contract; policy>debate; policy>evaluation; policy>gambling; policy>implementation; policy>insurance; policy>intent; policy>law; policy>lottery; policy>regulation; politeness>culture; politeness>shame; politician>appointment; politician>election; politician>government; politician>inheritance; politician>politics; politics>art; politics>coin; politics>commerce; politics>communication; politics>company; politics>contract; politics>corruption; politics>education; politics>election; politics>government; politics>individual; politics>inheritance; politics>justice; politics>law; politics>legislation; politics>majority; politics>monopoly; politics>negotiation; politics>parliament; politics>police; politics>property; politics>reform; politics>republic; politics>revenue; politics>science; politics>society; politics>tradition; politics>tribute; pollution>boat; pollution>cancer; pollution>carbon dioxide; pollution>carbon monoxide; pollution>chemical; pollution>climate change; pollution>coal; pollution>energy; pollution>global warming; pollution>industry; pollution>lead; pollution>litter; pollution>medication; pollution>medicine; pollution>ozone; pollution>paint; pollution>rash; pollution>recycling; pollution>smog; pollution>soil; pollution>temperature; pollution>throat; pollution>waste; pond>acre; pond>castle; pond>lake; pond>waterfall; pond>village; pony>genetics; pony>horse; pool>swimming pool; pop>population; pop>soft drink; popularity>cooperation; popularity>empathy; popularity>self-esteem; popularity>video game; population>human; population>human rights; population>poverty; population>religion; population>sex; population>species; pork>apple; pork>bacon; pork>beef; pork>bone; pork>cattle; pork>cholesterol; pork>fat; pork>ham; pork>meat; pork>mushroom; pork>rib; pork>sausage; pork>sheep; pork>shield; pork>shoe; pork>turkey; pork>vegetable; port>airport; port>canal; port>customs; port>harbour; port>road; portrait>emperor; portrait>government; portrait>king; portrait>literature; portrait>politics; portrait>sculpture; portrait>symbol; possession>ownership; possibility>fact; possibility>probability; post office>mail; post>column; post>mail; postcard>envelope; postcard>paper; postcard>photograph; postcard>reality; postcard>souvenir; postcard>stereotype; poster>apartment; poster>college; poster>concert; poster>film; poster>illustration; poster>music; poster>propaganda; poster>protest; poster>teenager; poster>tourism; pot>pottery; potato>carbon dioxide; potato>crop; potato>rice; potato>seed; potato>stomach; potato>wheat; potato>vitamin; potato>yogurt; potential>physics; pottery>archaeology; pottery>art; pottery>carbon monoxide; pottery>coal; pottery>electricity; pottery>gas; pottery>iron; pottery>turkey; pottery>wood; poverty>disease; poverty>disposable income; poverty>erosion; poverty>exchange rate; poverty>homelessness; poverty>hunger; poverty>literacy; poverty>pregnancy; poverty>racism; poverty>road; poverty>starvation; poverty>stereotype; praise>blame; praise>criticism; praise>motivation; praise>self-esteem; prayer>agriculture; prayer>apple; prayer>disease; prayer>language; prayer>love; prayer>mosque; prayer>religion; prayer>ritual; prayer>sin; prayer>sacrifice; prayer>sin; prayer>statistics; prayer>worship; prayer>yoga; precedent>appeal; precedent>contract; precedent>court; precedent>democracy; precedent>district; precedent>fact; precedent>law; precedent>professor; prediction>authority; prediction>engineering; prediction>experiment; prediction>future; prediction>hypothesis; prediction>insurance; prediction>measurement; prediction>navy; prediction>planning; prediction>politics; prediction>probability; prediction>revelation; prediction>risk; prediction>star; prediction>statistics; prediction>stock market; prediction>validity; preference>biology; preference>choice; preference>economics; preference>genetics; preference>happiness; preference>motivation; preference>psychology; prefix>suffix; pregnancy>abortion; pregnancy>bone; pregnancy>neck; pregnancy>pain; pregnancy>spinach; pregnancy>week; prejudices>disability; prejudice>empathy; prejudice>gender; prejudice>language; prejudice>nationality; prejudice>religion; premises>building; premises>negligence; premises>property; preparation>drug; preparation>food; present>day; present>future; present>god; present>light; present>paradigm; present>perception; present>star; present>time; presentation>lecture; presentation>speech; presenter>actor; presenter>comedian; presenter>film; presenter>journalist; presenter>local; presenter>museum; presenter>radio; presenter>singer; presenter>television; presenter>travel; presenter>university; presenter>weather forecast; preservation>toughness; presidency>president; presidency>prime minister; president>club; president>community; president>company; president>country; president>election; president>government; president>judge; president>leader; president>mayor; president>organization; president>parliament; president>prime minister; president>republic; president>turkey; president>university; president>war; pressure>area; pressure>density; pressure>explosion; pressure>fluid; pressure>force; pressure>gas; pressure>liquid; pressure>microphone; pressure>momentum; pressure>water; presumption>divorce; presumption>evidence; presumption>fraud; presumption>law; prevention>risk; price>commodity; price>cost; price>currency; price>dollar; price>euro; price>marketing; pride>assault; pride>death; pride>embarrassment; pride>emotion; pride>empire; pride>envy; pride>god; pride>human rights; pride>humility; pride>image; pride>justice; pride>kindness; pride>nation; pride>patience; pride>racism; pride>religion; pride>self-esteem; pride>selfishness; pride>shame; pride>sin; pride>synonym; pride>vanity; pride>virtue; pride>woman; priest>authority; priest>ceremony; priest>confirmation; priest>religion; priest>ritual; priest>sacrifice; priest>skirt; primary school>science; prime minister>chancellor; prime minister>constitution; prime minister>election; prime minister>government; prime minister>parliament; prime minister>privilege; prime minister>province; prime minister>turkey; prince>ceremony; prince>count; prince>emperor; prince>king; prince>law; prince>prefix; prince>princess; prince>realm; prince>treaty; princess>king; princess>prince; principal>debt; principle>biology; principle>cause; principle>conscience; principle>law; principle>physics; priority>requirement; prison>castle; prison>gym; prison>hospital; prison>imprisonment; prison>kitchen; prison>library; prison>police officer; prison>prisoner; prison>punishment; prison>suicide; prison>suspect; prison>war; prison>verdict; prisoner>arrest; prisoner>hostage; prisoner>human rights; prisoner>imprisonment; privacy>advertising; privacy>blanket; privacy>clothing; privacy>constitution; privacy>corporation; privacy>democracy; privacy>design; privacy>discrimination; privacy>earnings; privacy>email; privacy>fence; privacy>fraud; privacy>government; privacy>human rights; privacy>income; privacy>individual; privacy>security; privacy>solitude; privacy>towel; privacy>wall; prize>award; prize>controversy; prize>jealousy; prize>medal; prize>money; probability>artificial intelligence; probability>authority; probability>definition; probability>experiment; probability>finance; probability>gambling; probability>odds; probability>philosophy; probability>physics; probability>risk; probability>science; probability>statistics; probability>theory; probability>witness; problem>business; problem>doubt; problem>engineering; problem>inquiry; problem>question; problem>society; problem>walking; problem>worry; procedure>recipe; proceedings>textbook; procession>art; procession>carriage; procession>choir; procession>circus; procession>death; procession>funeral; procession>icon; procession>mayor; procession>parade; procession>poverty; procession>princess; procession>status symbol; procession>train; procession>wedding; produce>apple; produce>autumn; produce>berry; produce>broccoli; produce>cabbage; produce>crop; produce>cucumber; produce>farm; produce>fruit; produce>garlic; produce>grape; produce>harvest; produce>leak; produce>lemon; produce>lettuce; produce>melon; produce>onion; produce>pea; produce>peach; produce>pear; produce>region; produce>season; produce>spinach; produce>summer; produce>supermarket; produce>tomato; produce>vegetable; produce>winter; production>manufacturing; production>theatre; productivity>validity; profession>architect; profession>architecture; profession>examination; profession>law; profession>medicine; profession>pharmacy; profession>professional; profession>teaching; profession>training; profession>university; profession>vocation; professional>amateur; professional>electrician; professional>mind; professional>nurse; professional>plumber; professional>profession; professional>business; professor>college; professor>comedian; professor>design; professor>economics; professor>education; professor>engineering; professor>expert; professor>law; professor>lecture; professor>lecturer; professor>literature; professor>medicine; professor>mosque; professor>music; professor>protagonist; professor>psychologist; professor>research; professor>science; professor>seminar; professor>stereotype; professor>teacher; professor>university; programme>program; programmer>database; programmer>profession; programmer>video game; progression>education; progression>training; project>building; project>business; project>construction; project>contract; project>dissertation; project>engineer; project>goal; project>plan; project>science; project>task; project>team; promise>contract; promise>god; promise>noun; promise>prosperity; promise>verb; promise>vow; pronoun>adjective; pronoun>grammar; pronoun>noun; pronoun>preposition; pronunciation>education; pronunciation>language; proof>argument; proof>evidence; propaganda>advertising; propaganda>attention; propaganda>bias; propaganda>blame; propaganda>business; propaganda>cause; propaganda>deception; propaganda>education; propaganda>fear; propaganda>forgery; propaganda>laboratory; propaganda>leaflet; propaganda>lie; propaganda>news; propaganda>ownership; propaganda>persuasion; propaganda>rape; propaganda>slogan; propaganda>timber; propaganda>torture; propaganda>truth; propaganda>war; propaganda>west; property>abortion; property>capitalism; property>clothing; property>constitution; property>contract; property>corporation; property>economics; property>gift; property>god; property>government; property>idea; property>industry; property>interest; property>law; property>liberty; property>owner; property>ownership; property>parliament; property>regulation; property>religion; property>right; property>socialism; property>state; property>stock; property>tax; property>temple; property>theft; property>trade; property>wealth; proposal>proposition; proposition>belief; proposition>fact; proposition>logic; proposition>philosophy; proposition>psychology; proposition>truth; proposition>validity; prosecution>prosecutor; prosecutor>advocate; prosecutor>detective; prosecutor>judge; prosecutor>jury; prosecutor>law; prosecutor>magistrate; prosecutor>police; prosecutor>profession; prosecutor>solicitor; prosperity>ecology; prosperity>happiness; prosperity>health; prosperity>immune system; prosperity>income; prosperity>wealth; protagonist>audience; protagonist>narrative; protagonist>narrator; protagonist>tragedy; protection>safety; protection>security; protection>toughness; protein>acid; protein>atom; protein>blood; protein>digestion; protein>dna; protein>evolution; protein>feather; protein>gene; protein>hair; protein>lung; protein>muscle; protein>oxygen; protein>starvation; protein>virus; protest>bombing; protest>culture; protest>globalization; protest>government; protest>inflation; protest>injustice; protest>monopoly; protest>police; protest>policy; protest>revolution; protest>riot; protest>sport; protest>stock; protest>suicide; protest>war; proverb>advertising; proverb>literature; proverb>metaphor; proverb>paradox; proverb>rhyme; proverb>saying; provider>prostitute; province>constitution; province>country; province>county; province>education; province>magistrate; province>parliament; province>parody; province>region; province>republic; proximity>distance; psychiatrist>medicine; psychiatrist>profession; psychiatrist>psychologist; psychiatrist>psychology; psychologist>dissertation; psychologists>psychiatrist; psychologist>psychology; psychologist>seminar; psychologist>training; psychology>adaptation; psychology>anxiety; psychology>artificial intelligence; psychology>attention; psychology>chemistry; psychology>child; psychology>consciousness; psychology>death; psychology>education; psychology>emotion; psychology>evolution; psychology>experiment; psychology>explanation; psychology>happiness; psychology>information; psychology>interview; psychology>knowledge; psychology>laboratory; psychology>language; psychology>learning; psychology>medicine; psychology>memory; psychology>motivation; psychology>myth; psychology>pain; psychology>paradigm; psychology>perception; psychology>persuasion; psychology>philosophy; psychology>physics; psychology>pleasure; psychology>psychiatrist; psychology>psychologist; psychology>questionnaire; psychology>reasoning; psychology>school; psychology>stereotype; psychology>symbol; psychology>teaching; psychology>technology; psychology>thought; psychology>tool; pub>beer; pub>century; pub>dna; pub>freezer; pub>intellectual; pub>landlord; pub>nightclub; pub>pie; pub>pump; pub>stable; pub>tournament; public transport>airline; public transport>bus; public transport>canal; public transport>carbon dioxide; public transport>cd player; public transport>fare; public transport>ferry; public transport>passenger; public transport>pollution; public transport>revenue; public transport>rush hour; public transport>subsidy; public transport>traffic jam; publication>magazine; publication>newspaper; publicity>advertising; publicity>book; publicity>celebrity; publicity>employment; publicity>film; publicity>marketing; pudding>brand; pudding>butter; pudding>cereal; pudding>dessert; pudding>flour; pudding>milk; pudding>oven; pudding>rice; pudding>saucepan; pudding>sugar; pullover>gymnastics; pullover>sweater; pulse>blood; pulse>bone; pulse>elbow; pulse>heart; pulse>knee; pulse>light; pulse>leg; pulse>medicine; pulse>neck; pulse>wrist; pump>air conditioning; pump>energy; pump>gas; pump>liquid; pump>pressure; punctuation>alphabet; punctuation>drama; punctuation>full stop; punctuation>semicolon; punctuation>time; punctuation>usage; punctuation>writing; punishment>authority; punishment>child; punishment>cooperation; punishment>crime; punishment>criminal; punishment>law; punishment>liberty; punishment>pain; punishment>parent; punishment>prison; punishment>revenge; punishment>society; punishment>teacher; pupil>alcohol; pupil>cat; pupil>dog; pupil>evolution; pupil>fox; pupil>goat; pupil>horse; pupil>plural; pupil>sheep; puppy>dog; puppy>eye; puppy>kitten; purity>vice; purple>air; purple>blood; purple>blue; purple>capitalism; purple>emperor; purple>red; purple>rose; purple>sil; purple>soundtrack; purple>star; purple>sugar; purple>tennis; purple>wool; purpose>intention; purse>boxing; purse>handbag; purse>wallet; push>force; puzzle>game; puzzle>inquiry; puzzle>pattern; puzzle>problem; puzzle>research; puzzle>toy; puzzle>verb; pyramid>basketball; pyramid>brick; pyramid>millennium; pyramid>pottery; pyramid>temple; pyramid>tomb; pyramid>turkey; pyramid>volleyball; qualification>education; qualification>examination; qualification>tournament; quantity>circle; quantity>density; quantity>distance; quantity>energy; quantity>gender; quantity>heat; quantity>noun; quantity>person; quantity>pressure; quantity>ratio; quantity>time; quantity>volume; quarrel>arrow; query>question; quest>fantasy; quest>friendship; quest>hero; quest>literature; quest>temptation; question mark>diagnosis; question mark>exclamation mark; question mark>full stop; question mark>punctuation; question mark>semicolon; question

mark>university; question>answer; question>concept; question>debate; question>doubt; question>exam; question>examination; question>grammar; question>information; question>inquiry; question>logic; question>philosophy; question>problem; question>proposition; question>question mark; question>quiz; question>research; question>theory; question>truth; question>verb; question>questionnaire>question; questionnaire>research; questionnaire>statistics; quiz>silence; quiz>blog; quiz>game; quiz>radio; quiz>television; quotation>author; quotation>blog; quotation>cliché; quotation>email; quotation>film; quotation>painting; quotation>proverb; quotation>punctuation; quote>quotation; rabbit>animal; rabbit>cartoon; rabbit>cat; rabbit>desert; rabbit>disease; rabbit>dog; rabbit>forest; rabbit>fur; rabbit>gas; rabbit>grass; rabbit>gun; rabbit>luck; rabbit>mammal; rabbit>predator; rabbit>pregnancy; rabbit>species; rabbit>sheep; rabbit>sheep; rabbit>species; rabbit>vitamin; rabbit>woodland; rabbit>wool; racism>biology; racism>culture; racism>discrimination; racism>dislike; racism>education; racism>folk; racism>health care; racism>history; racism>human rights; racism>jazz; racism>nation; racism>philosophy; racism>politician; racism>prejudice; racism>statistics; racism>stereotype; racism>synonym; racism>violence; racism>xenophobia; racism>racism; racism>radiation>atom; radiation>cancer; radiation>energy; radiation>light; radiation>physics; radiation>red; radiation>spectrum; radiation>sun; radiation>thermometer; radiation>x-ray; radio>atom; radio>computer; radio>dvd; radio>electronics; radio>energy; radio>hobby; radio>horizon; radio>information; radio>invention; radio>investment; radio>light; radio>microphone; radio>mobile phone; radio>music; radio>regulation; radio>silky; radio>technology; radio>telecommunications; radio>television; radio>violin; radio>x-ray; raid>terrorist; rail>curtain; rain>agriculture; rain>atmosphere; rain>climate; rain>cloud; rain>continent; rain>desert; rain>drought; rain>flood; rain>global warming; rain>hail; rain>iron; rain>ocean; rain>parachute; rain>plant; rain>rainbow; rain>raincoat; rain>smoke; rain>snow; rain>soil; rain>storm; rain>summer; rain>thunder; rain>thunderstorm; rain>tornado; rain>umbrella; rain>water; rain>weather; rainbow>aeroplane; rainbow>angle; rainbow>blue; rainbow>cloud; rainbow>experiment; rainbow>fountain; rainbow>green; rainbow>helicopter; rainbow>horizon; rainbow>laser; rainbow>light; rainbow>red; rainbow>sunlight; rainbow>waterfall; rainbow>wave; rainbow>yellow; raincoat>rain; rainforest>acre; rainforest>adaptation; rainforest>aluminium; rainforest>bacteria; rainforest>bat; rainforest>bird; rainforest>branch; rainforest>butterfly; rainforest>carbon dioxide; rainforest>cloud; rainforest>coast; rainforest>eagle; rainforest>earth; rainforest>ecology; rainforest>extinction; rainforest>forest; rainforest>iron; rainforest>jungle; rainforest>leaf; rainforest>leopard; rainforest>lung; rainforest>mammal; rainforest>medicine; rainforest>monkey; rainforest>oxygen; rainforest>rain; rainforest>reptile; rainforest>river; rainforest>snake; rainforest>species; rainforest>sunlight; rainforest>tree; rainforest>turkey; rainforest>vegetation; rainforest>vine; rainforest>volcano; rank>hierarchy; rape>anger; rape>blackmail; rape>blood; rape>consent; rape>family; rape>friend; rape>human rights; rape>marriage; rape>police; rape>secondary school; rape>suicide; rape>war; rape>virgin; rash>anxiety; rash>blister; rash>bruise; rash>friction; rash>heat; rash>irritation; rash>pregnancy; rash>sun; rash>vaccine; rat>animal; rat>bean; rat>brain; rat>breed; rat>cat; rat>crime; rat>disease; rat>dog; rat>drug; rat>ecology; rat>experiment; rat>genetics; rat>health; rat>heart; rat>intelligence; rat>kidney; rat>liver; rat>mammal; rat>mouse; rat>noun; rat>psychology; rat>science fiction; rat>species; rat>suburb; rat>verb; rate>exchange rate; rating>evaluation; ratio>slope; ratio>television; razor>barber; razor>blade; razor>bread; razor>bronze; razor>cutlery; razor>tool; reality>astronomy; reality>consciousness; reality>culture; reality>disposition; reality>dream; reality>energy; reality>essence; reality>evolution; reality>existence; reality>fact; reality>fantasy; reality>fiction; reality>film; reality>future; reality>illusion; reality>imagination; reality>jargon; reality>knowledge; reality>language; reality>lie; reality>life; reality>matter; reality>measurement; reality>mind; reality>momentum; reality>nature; reality>necessity; reality>novel; reality>observation; reality>phenomenon; reality>philosophy; reality>physics; reality>politics; reality>present; reality>quantity; reality>reason; reality>religion; reality>science fiction; reality>space; reality>theory; reality>thought; reality>time; reality>truth; reality>virtual reality; reality>virtue; realm>empire; reason>argument; reason>art; reason>artificial intelligence; reason>behaviour; reason>belief; reason>calculation; reason>cause; reason>conscience; reason>consciousness; reason>economics; reason>fact; reason>faith; reason>fantasy; reason>feeling; reason>friendship; reason>head; reason>heart; reason>history; reason>human; reason>imagination; reason>inquiry; reason>institution; reason>intellect; reason>knowledge; reason>language; reason>law; reason>logic; reason>mind; reason>nature; reason>philosopher; reason>philosophy; reason>probability; reason>psychology; reason>reality; reason>religion; reason>revelation; reason>science; reason>space; reason>symbol; reason>theory; reason>thought; reason>time; reason>tradition; reason>truth; reason>wisdom; reason>wisdom; reason>rebellion; reason>rebellion>authority; reason>rebellion>behaviour; reason>rebellion>government; reason>rebellion>president; reason>rebellion>revolution; reason>rebellion>terrorism; receipt>euro; receipt>payment; receipt>tax; receipt>popularity; receipt>receipt; receptionist>receptionist; receptionist>business; receptionist>coffee; receptionist>company; receptionist>employee; receptionist>greeting; receptionist>interview; receptionist>mail; receptionist>office; receptionist>organization; receptionist>secretary; receptionist>tea; receptionist>telephone; recession>merger; recession>productivity; recipe>bay; recipe>food; recognition>award; record>document; record>recording; recording>data; recording>writing; recovery>cure; recreation>amusement; recreation>beach; recreation>employment; recreation>entertainment; recreation>fun; recreation>happiness; recreation>leisure; recreation>park; recreation>pleasure; recreation>seminar; recreation>sleep; recreation>tourism; recruit>recruitment; recruitment>advertising; recruitment>company; recruitment>employer; recruitment>employment; recruitment>knowledge; recruitment>literacy; recruitment>organization; recruitment>reference; recruitment>skill; rectangle>angle; rectangle>area; rectangle>butterfly; rectangle>circle; rectangle>green; rectangle>length; rectangle>square; rectangle>wire; recycling>aluminium; recycling>architect; recycling>chemist; recycling>computer; recycling>demand; recycling>economics; recycling>economist; recycling>electronics; recycling>energy; recycling>environmentalist; recycling>factory; recycling>finance; recycling>glass; recycling>gold; recycling>iron; recycling>law; recycling>lead; recycling>market; recycling>material; recycling>metal; recycling>mining; recycling>paper; recycling>plastic; recycling>resource; recycling>steel; recycling>sustainability; recycling>timber; recycling>warehouse; recycling>waste; recycling>wool; red>aggression; red>anger; red>autumn; red>beauty; red>blood; red>blue; red>boxing; red>cherry; red>courage; red>drum; red>dvd; red>fire; red>force; red>green; red>happiness; red>hate; red>heat; red>laser; red>love; red>medicine; red>night; red>oak; red>pottery; red>risk; red>rose; red>socialism; red>soft drink; red>south; red>sport; red>star; red>strawberry; red>sugar; red>sun; red>sunrise; red>temperature; red>time; red>tomato; red>turkey; red>war; red>well-being; red>violin; red>yellow; redevelopment>carbon footprint; referee>cricket; referee>female; referee>ice hockey; referee>sport; referee>volleyball; reference>art; reference>committee; reference>diary; reference>dictionary; reference>energy; reference>god; reference>invention; reference>knowledge; reference>library; reference>matter; reference>meeting; reference>negotiation; reference>noun; reference>prefix; reference>project; reference>pronoun; reference>referee; reference>referendum; reference>telephone; reference>validity; reference>word; referendum>alcohol; referendum>constitution; referendum>currency; referendum>election; referendum>euro; referendum>gerund; referendum>independence; referendum>initiative; referendum>law; referendum>majority; referendum>propaganda; referendum>republic; referendum>unity; referendum>vote; reform>hyphen; reform>revolution; reform>spelling; refuge>safety; refugee>anxiety; refugee>arrest; refugee>climate change; refugee>country; refugee>exile; refugee>government; refugee>human rights; refugee>male; refugee>nationality; refugee>passport; refugee>poverty; refugee>risk; refugee>slavery; refugee>suicide; refugee>turkey; refugee>war; refugee>violence; regime>geography; regime>measurement; region>atmosphere; region>climate; region>continent; region>county; region>culture; region>earth; region>earthquake; region>ecology; region>economics; region>exploration; region>geography; region>geology; region>human; region>ocean; region>politics; region>province; region>tourism; region>water; registration>register; regulation>contract; regulation>economics; regulation>employment; regulation>government; regulation>industry; regulation>information; regulation>law; regulation>monopoly; regulation>policy; regulation>pollution; regulation>price; regulation>society; regulation>wage; rehearsal>performance; reign>death; relation>diplomacy; relaxation>recreation; relevance>contradiction; relevance>description; relevance>distraction; relevance>economist; relevance>famine; relevance>intent; relevance>poverty; relief>bronze; relief>earth; relief>sun; religion>art; religion>belief; religion>culture; religion>dance; religion>education; religion>evolution; religion>experiment; religion>faith; religion>family; religion>festival; religion>funeral; religion>god; religion>government; religion>hospital; religion>law; religion>music; religion>philosophy; religion>politics; religion>prayer; religion>priest; religion>revelation; religion>ritual; religion>sacrifice; religion>science; religion>symbol; religion>temple; religion>terrorism; religion>theory; religion>worship; relish>cooking; relish>fruit; relish>garlic; relish>jam; relish>pear; relish>sauce; relish>vegetable; remains>body; remains>skeleton; remark>comment; remedy>cure; remedy>education; remedy>therapy; remorse>empathy; remorse>fear; remorse>marketing; remorse>psychology; remorse>resentment; remote control>dog; remote control>dvd; remote control>electronics; remote control>microphone; remote control>robot; remote control>television; remote control>tv; renovation>engineering; renovation>planning; renovation>repair; reply>answer; reply>question; report>presentation; reporter>journalist; representation>contract; reproduction>adult; reproduction>analogy; reproduction>animal; reproduction>bacteria; reproduction>bee; reproduction>bird; reproduction>evolution; reproduction>female; reproduction>fish; reproduction>genetics; reproduction>human; reproduction>life; reproduction>lottery; reproduction>male; reproduction>plant; reproduction>rabbit; reproduction>reptile; reproduction>seed; reproduction>sex; reproduction>shark; reproduction>virus; reptile>bird; reptile>crocodile; reptile>digestion; reptile>dinosaur; reptile>extinction; reptile>fish; reptile>heart; reptile>kidney; reptile>leather; reptile>lion; reptile>lung; reptile>mammal; reptile>oxygen; reptile>snake; republic>common sense; republic>constitution; republic>coup; republic>democracy; republic>independence; republic>president; republic>prime minister; reputation>assault; reputation>asset; reputation>auction; reputation>behaviour; reputation>belief; reputation>brand; reputation>business; reputation>candidate; reputation>citizen; reputation>community; reputation>company; reputation>competitor; reputation>consumer; reputation>cooperation; reputation>corporation; reputation>culture; reputation>customer; reputation>deception; reputation>definition; reputation>education; reputation>employee; reputation>evaluation; reputation>evolution; reputation>friendship; reputation>globalization; reputation>gossip; reputation>government; reputation>headache; reputation>honour; reputation>industry; reputation>interaction; reputation>investor; reputation>journalism; reputation>leadership; reputation>management; reputation>news; reputation>opinion; reputation>organization; reputation>person; reputation>phenomenon; reputation>potential; reputation>risk; reputation>role; reputation>science; reputation>social networking; reputation>stock market; reputation>sum; reputation>wealth; request>question; requirement>illusion; requirement>implementation; rescue>ambulance; rescue>court; rescue>helicopter; rescue>horse; rescue>injury; rescue>life; rescue>patient; rescue>police; rescue>prosecutor; rescue>tool; rescue>training; rescue>vehicle; rescue>wilderness; research>analysis; research>art; research>corporation; research>credibility; research>curiosity; research>dissertation; research>evidence; research>experiment; research>history; research>hypothesis; research>information; research>integrity; research>interpretation; research>knowledge; research>medicine; research>nature; research>scholar; research>science; research>theory; research>researcher; research>science; research>scientist; resemblance>similarity; resentment>anger; resentment>contempt; resentment>discrimination; resentment>envy; resentment>hatred; resentment>injustice; resentment>jealousy; resentment>prejudice; resentment>revenge; resentment>status; reserve>park; residence>home; residence>house; residence>patient; resignation>election; resignation>inheritance; resistance>friction; resort>beach; resort>coast; resort>entertainment; resort>golf; resort>hotel; resort>nightclub; resort>pub; resort>recreation; resort>restaurant; resort>skiing; resort>soft drink; resort>swimming pool; resort>tourism; resource>air; resource>benefit; resource>biology; resource>competition; resource>computer; resource>cost; resource>ecology; resource>economics; resource>fish; resource>infrastructure; resource>interest; resource>leadership; resource>management; resource>prosperity; resource>reproduction; resource>risk; resource>scarcity; resource>sustainability; resource>wage; resource>water; resource>wealth; respect>affection; respect>disrespect; respect>entity; respect>person; respect>pronoun; respect>rudeness; response>answer; response>output; responsibility>blame; responsibility>duty; responsibility>obligation; rest>leg; rest>leisure; rest>sleep; restaurant>business; restaurant>catering; restaurant>chef; restaurant>customer; restaurant>disability; restaurant>drink; restaurant>fast food; restaurant>hygiene; restaurant>lunch; restaurant>menu; restaurant>mess; restaurant>pub; restaurant>review; restaurant>steak; restaurant>waiter; restraint>brake; restraint>self-control; restriction>regulation; result>accuracy; result>advantage; result>calculation; result>change; result>competition; result>confrontation; result>credibility; result>democracy; result>disadvantage; result>economics; result>election; result>experiment; result>gain; result>game; result>information; result>injury; result>justice; result>lottery; result>phenomenon; result>relevance; result>research; result>science; result>sequence; result>statistics; result>war; result>victory; result>vote; retail>consumer; retail>department store; retail>download; retail>manufacturing; retail>marketing; retail>menu; retail>mp3 player; retail>pedestrian; retail>price; retail>recreation; retail>reputation; retail>roof; retail>shopping; retail>supermarket; retail>telephone; retail>trade; retail>workforce; retailer>retail; retirement>disability; retirement>employment; retirement>golf; retirement>hobby; retirement>inflation; retirement>investment; retirement>pension; retirement>researcher; retirement>sailing; retirement>saving; retirement>sport; retirement>stock market; retirement>tourism; retirement>volunteer; retreat>therapy; return>election; reward>award; revelation>angel; revelation>authority; revelation>god; revelation>materialism; revelation>miracle; revelation>physics; revelation>religion; revelation>scholar; revelation>sin; revenge>dignity; revenge>forgiveness; revenge>generation; revenge>honour; revenge>justice; revenge>murder; revenge>turkey; revenge>war; revenue>asset; revenue>bank; revenue>barber; revenue>business; revenue>cash; revenue>corporation; revenue>currency; revenue>expense; revenue>expenses; revenue>manufacturing; revenue>stock; revenue>book; review>car; review>computer; review>essay; review>film; review>socialist; review>video game; revolution>capitalism; revolution>coup; revolution>culture; revolution>democracy; revolution>discrimination; revolution>economy; revolution>force; revolution>harvest; revolution>history; revolution>philosophy; revolution>pump; revolution>rebellion; revolution>recession; revolution>reform; revolution>regime; revolution>religion; revolution>riot; revolution>society; revolution>technology; revolution>theory; revolution>war; rhyme>poem; rhyme>rhythm; rhyme>song; rhyme>syllable; rhyme>synonym; rhythm>dance; rhythm>drum; rhythm>jazz; rhythm>pattern; rhythm>stroke; rhythm>time; rib>bone; rib>chest; rib>fish; rib>frog; rib>heart; rib>lung; rib>neck; rib>reptile; rib>shark; rib>snake; rib>x-ray; ribbon>cloth; ribbon>ink; ribbon>metal; ribbon>plastic; ribbon>silky; ribbon>symbol; ribbon>velvet; ribbon>basket; ribbon>cereal; ribbon>disease; ribbon>pressure; ribbon>rat; ribbon>seed; ribbon>straw; ribbon>volume; riches>wealth; richness>wealth; rich>authority; riot>harvest; riot>hockey; riot>imprisonment; riot>people; riot>police; riot>property; riot>protest; riot>rebellion; riot>religion;

riot>revolution; riot>sport; riot>violence; rise>sunrise; risk>adventure; risk>ambiguity; risk>anxiety; risk>asset; risk>certainty; risk>crisis; risk>disaster; risk>emergency; risk>finance; risk>fraud; risk>gambling; risk>hazard; risk>insurance; risk>luck; risk>probability; risk>professional; risk>speculation; risk>threat; risk>uncertainty; risk>workplace; ritual>carnival; ritual>ceremony; ritual>community; ritual>dance; ritual>drink; ritual>food; ritual>music; ritual>psychology; ritual>religion; ritual>singing; ritual>tradition; ritual>worship; ritual>competition; rivalry>rival; river>bridge; river>canal; river>cave; river>cereals; river>drought; river>ferry; river>flood; river>lake; river>litre; river>mammal; river>ocean; river>planet; river>pressure; river>sailing; river>sand; river>sea; river>stream; river>tide; river>tunnel; river>water; river>waterfall; river>wool; road>brick; road>bridge; road>bus; road>city; road>cliff; road>concrete; road>copper; road>dirty; road>economics; road>erosion; road>ferry; road>lane; road>law; road>lead; road>motorway; road>mountain; road>pedestrian; road>person; road>planning; road>river; road>roundabout; road>sand; road>sea; road>slope; road>society; road>statistics; road>stream; road>street; road>traffic; road>traffic light; road>trail; road>travel; road>tree; road>waste; road>vegetation; road>vehicle; road>village; robbery>blackmail; robbery>burglary; robbery>crime; robbery>intention; robbery>mobile phone; robbery>theft; robbery>weapon; robot>artificial intelligence; robot>disability; robot>electronics; robot>laboratory; robot>legend; robot>pharmacist; robot>planet; robot>technology; robot>theatre; robot>virtual reality; robot>volcano; rock>jewellery; rocket>acre; rocket>aircraft; rocket>bomb; rocket>firework; rocket>flight; rocket>light; rocket>force; rocket>fuel; rocket>helicopter; rocket>landing; rocket>legend; rocket>light; rocket>missile; rocket>oxygen; rocket>parachute; rocket>petrol; rocket>rescue; rocket>satellite; rocket>weapon; rocket>vehicle; role>ambiguity; role>behaviour; role>economics; role>electrician; role>genetics; role>philosophy; role>punishment; role>right; role>shopkeeper; role>society; roll>role; roof>aluminium; roof>arch; roof>banana; roof>building; roof>cathedral; roof>ceiling; roof>construction; roof>copper; roof>electricity; roof>heat; roof>house; roof>lead; roof>legislation; roof>material; roof>rain; roof>snow; roof>stadium; roof>steel; roof>straw; roof>sunlight; roof>timber; roof>weather; roof>wind; room>bathroom; room>bedroom; room>box; room>door; room>kitchen; room>staircase; room>suburb; room>wall; roommate>apartment; roommate>loneliness; roommate>privacy; root>bacteria; root>carrot; root>cherry; root>iron; root>mango; root>plant; root>potato; root>strawberry; root>temple; root>tree; root>water; rope>anchor; rope>chain; rope>construction; rope>cotton; rope>fibre; rope>grass; rope>knot; rope>leather; rope>linen; rope>sail; rope>silk; rope>straw; rope>wool; rose>alcohol; rose>chocolate; rose>coast; rose>deer; rose>erosion; rose>flower; rose>herb; rose>insect; rose>jam; rose>leaf; rose>plant; rose>root; rose>sand; round>circle; round>sphere; roundabout>bicycle; roundabout>motorist; roundabout>pedestrian; roundabout>traffic light; roundabout>tram; roundabout>van; row>controversy; rubbish>waste; rudeness>cough; rudeness>crime; rudeness>dignity; rudeness>gender; rudeness>insult; rudeness>library; rudeness>mask; rudeness>mobile phone; rudeness>noise; rudeness>politeness; rudeness>religion; rudeness>snob; rug>carpet; rugby>swimming pool; rule>government; rule>law; ruler>rule; ruler>lead; ruler>waist; ruling>rule; run>running; run>stream; runner>running; running>endurance; running>jogging; running>marathon; running>mud; running>oxygen; running>speed; running>walking; runway>aircraft; runway>brick; runway>concrete; runway>coral; runway>density; runway>distance; runway>grass; runway>ice; runway>landing; runway>salt; runway>sand; runway>snow; runway>soil; runway>weather; runway>wind; rush hour>construction; rush hour>fare; rush hour>fast food; rush hour>festival; rush hour>lunchtime; rush hour>public transport; rush hour>restaurant; rush hour>traffic; rush hour>train; rush hour>weather; rush hour>worship; sack>bag; sack>bed; sacrifice>civilization; sacrifice>death; sacrifice>god; sacrifice>metaphor; sacrifice>murder; sacrifice>sun; sacrifice>worship; saddle>camel; saddle>cattle; saddle>horse; saddle>pressure; saddle>status symbol; saddle>sword; sadness>anger; sadness>disgust; sadness>empathy; sadness>fear; sadness>happiness; sadness>pupil; safety>accident; safety>aircraft; safety>awareness; safety>bicycle; safety>boat; safety>child; safety>error; safety>guarantee; safety>harm; safety>insurance; safety>regulation; safety>risk; safety>roundabout; safety>security; safety>traffic light; safety>training; sail>kite; sail>machine; sail>recreation; sail>sailing; sail>wind; sail>yacht; sailing>anchor; sailing>crew; sailing>fishing; sailing>geography; sailing>history; sailing>port; sailing>recreation; sailing>sail; sailing>sailor; sailing>weather; sailing>wind; sailing>windsurfing; sailing>wing; sailing>yacht; sailor>air conditioning; sailor>electrician; sailor>iceberg; sailor>navy; sailor>nurse; sailor>sail; sailor>sailing; saint>belief; saint>god; saint>heaven; saint>icon; saint>revelation; saint>virtue; saint>worship; salad>appetite; salad>bacon; salad>beef; salad>carrot; salad>casserole; salad>cheese; salad>cucumber; salad>dessert; salad>fruit; salad>fish; salad>herb; salad>lettuce; salad>main course; salad>meal; salad>meat; salad>milk; salad>mushroom; salad>onion; salad>pasta; salad>salmon; salad>sandwich; salad>sauce; salad>spice; salad>spinach; salad>steak; salad>supermarket; salad>tomato; salad>vegetable; salad>vinegar; salad>yogurt; salad>yogurt; salary>beer; salary>corporation; salary>office; salary>overtime; salary>partnership; salary>profession; salary>salt; salary>slavery; salary>soldier; salary>wage; salary>willage; salmon>cholesterol; salmon>protein; salmon>species; sail>animal; salt>fire; salt>iron; salt>mining; salt>plastic; salt>pregnancy; salt>rice; salt>salary; salt>soap; salt>stroke; salt>sunlight; salt>taste; salt>water; sand>agriculture; sand>beach; sand>brick; sand>concrete; sand>coral; sand>erosion; sand>flour; sand>glass; sand>iron; sand>material; sand>paint; sand>soil; sandal>ankle; sandal>boot; sandal>fashion; sandal>foot; sandal>leather; sandal>rope; sandal>rubber; sandal>shoe; sandal>therapy; sandal>toe; sandal>trekking; sandal>wood; sandal>yoga; sandwich>bread; sandwich>cheese; sandwich>ham; sandwich>meat; sandwich>picnic; sandwich>sauce; satellite>circle; satellite>climate; satellite>earth; satellite>human; satellite>image; satellite>inclination; satellite>landing; satellite>planet; satellite>shadow; satellite>sun; satellite>telecommunications; satellite>turkey; saturday>day; saturday>friday; saturday>harvest; saturday>hour; saturday>purple; saturday>slang; saturday>sun; saturday>sunday; saturday>sweets; saturday>thursday; saturday>week; saturday>weekend; sauce>beef; sauce>cooking; sauce>dessert; sauce>food; sauce>fruit; sauce>ham; sauce>liquid; sauce>pork; sauce>potato; sauce>salad; sauce>tomato; sauce>vegetable; saucer>cat; saucer>coffee; saucer>spoon; saucer>tea; sausage>barbecue; sausage>beef; sausage>beer; sausage>blood; sausage>bread; sausage>breakfast; sausage>butcher; sausage>carrot; sausage>casserole; sausage>comedy; sausage>cooking; sausage>deer; sausage>food; sausage>heat; sausage>hierarchy; sausage>industry; sausage>kangaroo; sausage>leek; sausage>lemon; sausage>lunch; sausage>onion; sausage>plastic; sausage>poet; sausage>pork; sausage>potato; sausage>pudding; sausage>ratio; sausage>salmon; sausage>sandwich; sausage>stomach; sausage>taste; sausage>vegetable; sausage>vegetarian; sausage>wine; sausage>vinegar; saving>bank; saving>cost; saving>income; saving>interest; saving>investment; saving>money; saving>pension; saving>recession; savings>saving; saying>cliché; saying>idiom; saying>proverb; scar>accident; scar>bone; scar>chest; scar>disease; scar>fat; scar>heart; scar>injury; scar>muscle; scar>pregnancy; scar>shoulder; scar>skin; scar>surgery; scar>wound; scarcity>extinction; scarcity>resource; scarcity>society; scarcity>species; scarf>colour; scarf>fabric; scarf>fashion; scarf>garment; scarf>religion; scarf>waist; scarf>wool; scenario>ballet; scenario>composer; scenario>opera; scene>scenery; scene>breakfast; school>classroom; school>college; school>education; school>gang; school>gym; school>health care; school>institution; school>leisure; school>library; school>lunch; school>mosque; school>office; school>primary school; school>secondary school; school>self-esteem; school>soldier; school>student; school>teacher; school>toddler; school>university; school>vandalism; schoolchild>child; schooling>school; science fiction>archaeology; science fiction>artificial intelligence; science fiction>chemistry; science fiction>computer; science fiction>disaster; science fiction>economics; science fiction>electricity; science fiction>email; science fiction>fantasy; science fiction>fiction; science fiction>film; science fiction>future; science fiction>history; science fiction>imagination; science fiction>innovation; science fiction>narrative; science fiction>novel; science fiction>optimism; science fiction>physics; science fiction>psychology; science fiction>satellite; science fiction>science; science fiction>technology; science fiction>video game; science>accuracy; science>astronomy; science>biology; science>calculator; science>cancer; science>certainty; science>chemistry; science>civilization; science>concept; science>dna; science>electronics; science>energy; science>engineering; science>entertainment; science>evolution; science>fact; science>formula; science>geology; science>hygiene; science>hypothesis; science>knowledge; science>literature; science>logic; science>measurement; science>medicine; science>mobile phone; science>nature; science>observation; science>phenomenon; science>philosophy; science>physics; science>poetry; science>policy; science>politician; science>potential; science>psychology; science>religion; science>research; science>science fiction; science>scientist; science>society; science>species; science>statistics; science>technology; science>telecommunications; science>television; science>theory; science>truth; science>vaccination; science>watch; scientist>archaeologist; scientist>artificial intelligence; scientist>astronomy; scientist>biology; scientist>blood; scientist>career; scientist>chemist; scientist>chemistry; scientist>computer; scientist>data; scientist>disease; scientist>ecology; scientist>economist; scientist>electronics; scientist>engineer; scientist>experiment; scientist>genetics; scientist>heat; scientist>human; scientist>knowledge; scientist>laboratory; scientist>light; scientist>matter; scientist>medicine; scientist>mind; scientist>music; scientist>musician; scientist>nature; scientist>number; scientist>nurse; scientist>observation; scientist>perception; scientist>philosophy; scientist>physics; scientist>planet; scientist>priest; scientist>probability; scientist>profession; scientist>psychologist; scientist>reality; scientist>science; scientist>technology; scientist>thought; scientist>world; scissors>barber; scissors>blade; scissors>branch; scissors>bronze; scissors>child; scissors>cloth; scissors>fingernail; scissors>food; scissors>grass; scissors>hair; scissors>hairdresser; scissors>iron; scissors>metal; scissors>moustache; scissors>paper; scissors>pillow; scissors>plastic; scissors>rope; scissors>rubber; scissors>surgery; scissors>toenail; scissors>wire; scissors>wool; scrap>pottery; scrap>death; scrap>engine; scrap>injury; scrap>machinery; scrap>waste; scratch>ice hockey; scratch>money; scratch>video game; screen>cable; screen>television; sculpture>aluminium; sculpture>archaeology; sculpture>architecture; sculpture>bicycle; sculpture>bronze; sculpture>concrete; sculpture>emperor; sculpture>glass; sculpture>gold; sculpture>jewellery; sculpture>mask; sculpture>material; sculpture>medal; sculpture>metal; sculpture>museum; sculpture>oak; sculpture>paint; sculpture>pottery; sculpture>proverb; sculpture>relief; sculpture>silver; sculpture>statue; sculpture>steel; sculpture>stone; sculpture>temperature; sculpture>theft; sculpture>wood; sea>aircraft; sea>art; sea>bacteria; sea>carbon dioxide; sea>coal; sea>cod; sea>commodity; sea>composer; sea>copper; sea>coral; sea>environmentalist; sea>fish; sea>friction; sea>gold; sea>infrastructure; sea>iron; sea>lake; sea>lead; sea>literature; sea>ocean; sea>oil; sea>opera; sea>oxygen; sea>penguin; sea>poetry; sea>port; sea>protagonist; sea>reptile; sea>river; sea>robot; sea>sailing; sea>salmon; sea>sand; sea>science fiction; sea>silver; sea>skeleton; sea>species; sea>sun; sea>surfing; sea>symbol; sea>theatre; sea>tide; sea>transport; sea>tuna; sea>war; sea>whale; sea>virus; season>astronomy; season>autumn; season>calendar; season>climate; season>data; season>daylight; season>definition; season>diagram; season>earth; season>ecology; season>month; season>noon; season>ocean; season>rain; season>snow; season>summer; season>sun; season>sunlight; season>tornado; season>weather; season>wind; season>winter; season>year; seat>bench; seat>chair; seat>saddle; seat>throne; second>clock; second>day; second>earth; second>hour; second>minute; second>time; secondary school>college; secondary school>geography; secondary school>history; secondary school>institution; secondary school>primary school; secondary school>science; secondary school>university; secretary>economics; secretary>receptionist; secretary>university; sector>area; sector>region; security>advertisement; security>burglar; security>information; security>insecurity; security>intruder; security>police; security>risk; security>safety; security>threat; security>>window; seed>animal; seed>ant; seed>apple; seed>bean; seed>bird; seed>cereal; seed>cherry; seed>coconut; seed>cooking; seed>cotton; seed>digestion; seed>fish; seed>flower; seed>forest; seed>fruit; seed>light; seed>mammal; seed>oak; seed>pea; seed>peach; seed>peanut; seed>pine; seed>plant; seed>potato; seed>protein; seed>rain; seed>reproduction; seed>reptile; seed>snow; seed>spice; selection>evolution; selection>genetics; self>consciousness; self>individual; self>sin; self>assurance>self-confidence; self-awareness>artificial intelligence; self-awareness>confidence; self-awareness>consciousness; self-awareness>elephant; self-awareness>intelligence; self-awareness>person; self-awareness>reality; self-awareness>reasoning; self-awareness>science fiction; self-awareness>scientist; self-awareness>soul; self-confidence>confidence; self-confidence>psychology; self-confidence>self-esteem; self-confidence>vanity; self-control>emotion; self-control>psychology; self-esteem>acceptance; self-esteem>animal; self-esteem>biology; self-esteem>chemistry; self-esteem>creativity; self-esteem>education; self-esteem>emotion; self-esteem>experiment; self-esteem>feeling; self-esteem>happiness; self-esteem>love; self-esteem>measurement; self-esteem>perception; self-esteem>person; self-esteem>pride; self-esteem>psychology; self-esteem>self-awareness; self-esteem>self-confidence; self-esteem>sense; self-esteem>shame; self-esteem>shyness; self-esteem>teaching; selfishness>economy; selfishness>empathy; selfishness>generosity; selfishness>philosophy; selfishness>psychology; selfishness>religion; self-respect>self-esteem; semicolon>clause; semicolon>comma; semicolon>exclamation mark; semicolon>full stop; semicolon>punctuation; semicolon>question mark; semicolon>word; semicolon>debate; seminar>lecture; seminar>university; sensation>sense; sense>attention; sense>bat; sense>bee; sense>bird; sense>blindness; sense>blood; sense>communication; sense>dolphin; sense>drug; sense>illusion; sense>insect; sense>light; sense>pain; sense>perception; sense>pressure; sense>psychologist; sense>reptile; sense>shark; sense>skin; sense>snake; sense>sound; sense>sweet; sense>taste; sense>throat; sense>time; sense>tongue; sense>touch; sensibility>emotion; sentiment>emotion; sentiment>feeling; september>autumn; september>day; september>month; september>school; september>year; sequence>bit; sequence>uncountable; series>episode; series>sequence; series>serial; series>species; set>gang; set>jargon; set>onion; set>potato; set>setting; set>tennis; setback>problem; setting>classroom; sewing>archaeology; sewing>bone; sewing>clothing; sewing>computer; sewing>craft; sewing>fashion; sewing>fur; sewing>hobby; sewing>leather; sewing>pin; sewing>sailing; sewing>vein; sex>ant; sex>bird; sex>dna; sex>evolution; sex>female; sex>fish; sex>flower; sex>genetics; sex>human; sex>insect; sex>male; sex>mammal; sex>mushroom; sex>pine; sex>reptile; sex>seed; sex>species; shade>mud; shade>sunglasses; shadow>aircraft; shadow>dimension; shadow>earth; shadow>ghost; shadow>light; shadow>shade; shadow>space; shadow>steam; shadow>sun; shadow>wind; shame>blame; shame>contempt; shame>culture; shame>embarrassment; shame>emotion; shame>humility; shame>punishment; shampoo>acid; shampoo>coconut; shampoo>dirty; shampoo>fragrance; shampoo>hair; shampoo>infant; shampoo>irritation; shampoo>lemon; shampoo>olive; shampoo>peanut; shampoo>rice; shampoo>soap; shampoo>straw; shampoo>surgery; shampoo>water; shampoo>vinegar; shape>circle; shape>curve; shape>dimension; shape>sphere; shape>square; shark>animal; shark>arm; shark>blood; shark>cancer; shark>crystal; shark>earth; shark>eye; shark>fish; shark>god; shark>hair; shark>heart; shark>jaw; shark>kidney; shark>leather; shark>mammal; shark>muscle; shark>nose;

shark>ocean; shark>offspring; shark>oxygen; shark>protein; shark>pupils; shark>skate; shark>skeleton; shark>status symbol; shark>supermarket; shark>tail; shed>aluminium; shed>barn; shed>farm; shed>gardening; shed>hobby; shed>jazz; shed>plastic; shed>tool; shed>tunnel; shed>wood; shed>workshop; sheep>abortion; sheep>adaptation; sheep>agriculture; sheep>animal; sheep>antibiotic; sheep>beef; sheep>carpet; sheep>copper; sheep>dialect; sheep>genetics; sheep>grass; sheep>idiom; sheep>lip; sheep>mammal; sheep>metaphor; sheep>pig; sheep>reproduction; sheep>saint; sheep>tongue; sheep>vaccination; sheep>weed; sheep>virus; sheep>wool; sheep>worm; sheet>paper; sheet>video game; shelter>homelessness; shield>arrow; shield>circle; shield>electronics; shield>leather; shield>metal; shield>police; shield>sword; shield>wood; ship>anchor; ship>boat; ship>cancer; ship>cargo; ship>circle; ship>crab; ship>density; ship>engineer; ship>ferry; ship>fishing; ship>formula; ship>fruit; ship>genetics; ship>globalization; ship>gold; ship>grass; ship>historian; ship>immune system; ship>jail; ship>lake; ship>meat; ship>navy; ship>ocean; ship>port; ship>railway; ship>recycling; ship>river; ship>sail; ship>sailing; ship>sailor; ship>salmon; ship>scrap; ship>sea; ship>strap; ship>weather; ship>wheat; ship>wind; shirt>button; shirt>cotton; shirt>dress; shirt>infant; shirt>jacket; shirt>pocket; shirt>silk; shirt>sleep; shirt>sleeve; shirt>socialist; shirt>sweater; shirt>sweatshirt; shirt>trousers; shirt>t-shirt; shirt>waist; shirt>vest; shirt>wool; shoe>ankle; shoe>archaeologist; shoe>baseball; shoe>basketball; shoe>blisters; shoe>bone; shoe>boot; shoe>civilization; shoe>climate; shoe>construction; shoe>copper; shoe>cotton; shoe>dance; shoe>dancing; shoe>design; shoe>dog; shoe>elephant; shoe>fashion; shoe>foot; shoe>friction; shoe>glue; shoe>golf; shoe>heel; shoe>hip; shoe>horse; shoe>human; shoe>hunting; shoe>ice; shoe>ice cream; shoe>knee; shoe>leather; shoe>marathon; shoe>metal; shoe>mining; shoe>mosque; shoe>museum; shoe>peasant; shoe>plastic; shoe>police; shoe>revenue; shoe>rice; shoe>rubber; shoe>running; shoe>sandal; shoe>skateboarding; shoe>ski; shoe>skiing; shoe>slavery; shoe>snow; shoe>status symbol; shoe>steel; shoe>turkey; shoe>uniform; shoe>water; shoe>wood; shooting>combat; shooting>crime; shooting>hunting; shooting>missile; shooting>rocket; shooting>weapon; shop>garment; shop>market; shop>retail; shop>shopping; shop>workshop; shopkeeper>management; shopping>ad; shopping>brand; shopping>business; shopping>department store; shopping>disposable income; shopping>leisure; shopping>logo; shopping>marketing; shopping>negotiation; shopping>pharmacy; shopping>price; shopping>religion; shopping>retail; shopping>supermarket; shopping>trade; shore>beach; shore>coast; shore>erosion; shore>geology; shore>lake; shore>ocean; shore>sea; shorts>basketball; shorts>dress; shorts>jeans; shorts>pocket; shorts>skirt; shorts>sport; shorts>trousers; shot>shooting; shoulder>bat; shoulder>joint; shoulder>pain; show>concert; show>theatre; shower>bathroom; shower>curtain; shower>door; shower>efficiency; shower>hygiene; shower>shampoo; shower>soap; shower>swimming pool; shower>waterfall; shuttle>public transport; shyness>aggression; shyness>anxiety; shyness>child; shyness>conversation; shyness>discomfort; shyness>family; shyness>fear; shyness>feeling; shyness>gene; shyness>hypothesis; shyness>panic; shyness>pregnancy; shyness>proximity; shyness>psychology; shyness>self-confidence; sibling>aggression; sibling>cousin; sibling>dna; sibling>father; sibling>hostility; sibling>inheritance; sibling>love; sibling>mother; sickness>disease; sickness>illness; side effect>drug; side effect>medicine; side effect>pain; side effect>x-ray; side>pirate; side>slavery; side>turkey; sightseeing>tourism; sign>biology; sign>coincidence; sign>communication; sign>flag; sign>full stop; sign>gesture; sign>icon; sign>indication; sign>language; sign>logic; sign>medicine; sign>notice; sign>people; sign>philosophy; sign>poetry; sign>religion; sign>signature; sign>symptom; sign>thunder; signal>telecommunications; signal>traffic light; silence>anger; silence>communication; silence>composer; silence>debate; silence>emotion; silence>mobile phone; silence>piano; silence>sound; silence>speech; silk>angle; silk>ant; silk>bee; silk>carpet; silk>dress; silk>electricity; silk>fibre; silk>glue; silk>light; silk>monopoly; silk>parachute; silk>protein; silk>shirt; silk>spider; silk>tobacco; silk>trade; silk>triangle; silk>turkey; silk>wasp; silver>aluminium; silver>bacteria; silver>brass; silver>carbon; silver>coin; silver>concentration; silver>copper; silver>cutlery; silver>diamond; silver>explosive; silver>female; silver>fiction; silver>gold; silver>hammer; silver>infection; silver>iron; silver>lead; silver>metal; silver>mirror; silver>myth; silver>ozone; silver>planet; silver>salt; silver>silk; silver>steel; silver>tea; silver>tin; silver>wine; simplicity>beauty; simplicity>complexity; simplicity>elegance; simplicity>truth; simplification>validity; simulation>aircraft; simulation>biology; simulation>chemistry; simulation>economics; simulation>education; simulation>engineering; simulation>experiment; simulation>film; simulation>finance; simulation>function; simulation>lie; simulation>physics; simulation>prediction; simulation>risk; simulation>scenario; simulation>software; simulation>statistics; simulation>technology; simulation>television; simulation>terrorism; simulation>training; simulation>truth; simulation>video game; simulation>virtual reality; sin>blame; sin>evil; sin>heaven; sin>hell; sin>vanity; sincerity>honesty; sincerity>irony; sincerity>virtue; singer>singing; singer>audition; singing>bird; singing>chest; singing>choir; singing>composer; singing>consonant; singing>culture; singing>dolphin; singing>ear; singing>harmony; singing>hip-hop; singing>human; singing>immune system; singing>jazz; singing>lip; singing>lyrics; singing>melody; singing>microphone; singing>music; singing>neck; singing>opera; singing>rhyme; singing>rhythm; singing>security; singing>song; singing>speech; singing>tongue; singing>whale; singing>vowel; single>slang; sink>bathroom; sink>concrete; sink>copper; sink>flower; sink>frying pan; sink>glass; sink>kitchen; sink>noise; sink>plastic; sink>soap; sink>steel; sink>wood; sir>ambassador; sir>inspector; sir>lady; sir>madam; sir>police; sir>professor; sir>slang; siren>son; sister>sibling; sister-in-law>wife; site>construction; site>website; sitting room>living room; size>area; size>dimension; size>height; size>length; size>measurement; size>statistics; size>width; size>volume; skate>animal; skateboard>skateboarding; skateboard>turn; skateboarding>aluminium; skateboarding>bruise; skateboarding>profession; skateboarding>skateboard; skateboarding>surfing; skateboarding>transportation; skating>ice skating; skating>skateboarding; skeleton>adaptation; skeleton>animal; skeleton>ant; skeleton>beak; skeleton>bone; skeleton>coral; skeleton>ear; skeleton>elephant; skeleton>fish; skeleton>flight; skeleton>horse; skeleton>human; skeleton>infant; skeleton>insect; skeleton>jaw; skeleton>muscle; skeleton>nerve; skeleton>nose; skeleton>shark; skeleton>structure; skeleton>tongue; ski>skiing; ski>snowboarding; skiings>ski; skiing>snow; skiings>snowboarding; skill>baker; skill>economy; skill>empathy; skill>energy; skill>language; skill>leadership; skill>learning; skill>motivation; skill>respect; skill>self; skill>teamwork; skill>technology; skills>time; skin>animal; skin>bacteria; skin>bird; skin>blood; skin>body; skin>bone; skin>carbon dioxide; skin>cattle; skin>clothing; skin>cow; skin>fat; skin>feather; skin>fish; skin>frog; skin>fur; skin>goat; skin>hair; skin>heat; skin>horse; skin>injury; skin>leather; skin>muscle; skin>nerve; skin>oxygen; skin>pig; skin>poison; skin>pressure; skin>protein; skin>repair; skin>reptile; skin>scar; skin>sheep; skin>skull; skin>sweat; skin>temperature; skin>touch; skin>water; skirt>culture; skirt>denim; skirt>fashion; skirt>garment; skirt>jeans; skirt>leather; skirt>leg; skirt>man; skirt>trousers; skirt>t-shirt; skirt>underwear; skirt>waist; skirt>woman; skull>ancestor; skull>animal; skull>bird; skull>bone; skull>brain; skull>elephant; skull>face; skull>head; skull>jaw; skull>lion; skull>mammal; skull>mouse; skull>shark; skull>skeleton; sky>agriculture; sky>air; sky>aircraft; sky>astronomy; sky>atmosphere; sky>bat; sky>bird; sky>blue; sky>calendar; sky>city; sky>down; sky>daylight; sky>earth; sky>flight; sky>fog; sky>green; sky>horizon; sky>human; sky>insect; sky>legend; sky>lightning; sky>moonlight; sky>night; sky>ocean; sky>planet; sky>plant; sky>rain; sky>rainbow; sky>seed; sky>shadow; sky>smog; sky>species; sky>star; sky>storm; sky>sun; sky>sunlight; sky>sunrise; sky>sunset; sky>thunder; sky>thunderstorm; sky>weather; sky>wind; slang>crime; slang>crime; slang>dialect; slang>jargon; slang>language; slang>musician; slang>sex; slang>violence; slang>word; slap>fight; slap>mobile phone; slap>slang; slap>wrist; slaughter>massacre; slaughter>murder; slave>slavery; slavery>adoption; slavery>culture; slavery>human rights; slavery>property; slavery>tax; sleep>adolescent; sleep>alarm clock; sleep>bed; sleep>consciousness; sleep>dolphin; sleep>immune system; sleep>insomnia; sleep>memory; sleep>narrative; sleep>reasoning; sleep>tobacco; sleeve>arm; sleeve>garment; sleeve>ribbon; sleeve>shoulder; sleeve>wedding; slogan>phrase; slope>curve; slope>geography; slope>road; slot>castle; smile>amusement; smile>animal; smile>anxiety; smile>ball; smile>dishonesty; smile>embarrassment; smile>emotion; smile>fear; smile>frown; smile>happiness; smile>human; smile>laughter; smile>muscle; smile>pleasure; smile>psychology; smog>carbon monoxide; smog>coal; smog>flu; smog>fog; smog>ozone; smog>smoke; smog>aluminium; smog>cable; smog>cancer; smog>candle; smog>carbon; smog>carbon dioxide; smog>carbon monoxide; smog>cloud; smog>copper; smog>death; smog>plastic; smog>fire; smog>firefighter; smog>fireplace; smog>fuel; smog>gas; smog>iron; smog>lead; smog>liquid; smog>lung; smog>mist; smog>oil; smog>plastic; smog>poison; smog>smog; smog>smoking; smog>toast; smog>tobacco; smog>wood; smog>smoke; smog>smoking; smoking>carbon monoxide; smoking>cigarette; smoking>jazz; smoking>lighter; smoking>match; smoking>tobacco; snack>attention; snack>cheese; snack>food; snack>fruit; snack>meal; snack>meat; snack>obesity; snack>seed; snack>sugar; snack>vegetable; snack>vitamin; snake>brass; snake>chicken; snake>digestion; snake>dinosaur; snake>evil; snake>feather; snake>jaw; snake>lung; snake>medicine; snake>mouth; snake>protein; snake>reptile; snake>skeleton; snake>skull; snake>species; snake>worm; snob>advertising; snob>beauty; snob>education; snob>intellect; snob>nationality; snob>pride; snob>wealth; snow>agriculture; snow>carrot; snow>cloud; snow>concrete; snow>crystal; snow>fall; snow>frost; snow>hail; snow>ice; snow>landscape; snow>light; snow>mountain; snow>photography; snow>pressure; snow>river; snow>salt; snow>ski; snow>skiing; snow>snowboarding; snow>space; snow>spectrum; snow>summer; snow>sunlight; snow>water; snow>wind; snowboard>carbon; snowboard>skateboarding; snowboard>ski; snowboard>snowboarding; snowboarding>skateboarding; snowboarding>skiing; snowboarding>snowboard; snowboarding>surfing; soap opera>abortion; soap opera>adoption; soap opera>episode; soap opera>fantasy; soap opera>magazine; soap opera>murder; soap opera>rape; soap opera>soap; soap opera>soap; soap opera>theft; soap opera>trilogy; soap opera>twin; soap>advertising; soap>aluminium; soap>dust; soap>hotel; soap>hygiene; soap>sacrifice; soap>sand; soap>silver; soap>toothpaste; soap>water; soap>wire; soap>wool; socialism>agriculture; socialism>authority; socialism>capitalism; socialism>hierarchy; socialism>human rights; socialism>interest; socialism>materialist; socialism>money; socialism>poverty; socialism>rebellion; socialism>republic; socialism>socialist; socialist>socialism; society>agriculture; society>artificial intelligence; society>business; society>capitalism; society>civilization; society>commerce; society>community; society>cooperation; society>culture; society>education; society>geography; society>government; society>hierarchy; society>history; society>industry; society>infrastructure; society>institution; society>investor; society>language; society>leadership; society>organization; society>religion; society>technology; society>trade; society>tribe; society>wealth; sock>boot; sock>cloth; sock>clothing; sock>cotton; sock>foot; sock>glove; sock>linen; sock>shoe; sock>silk; sock>stocking; sock>sweat; sock>wool; soft drink>acid; soft drink>bottle; soft drink>carbon dioxide; soft drink>cola; soft drink>erosion; soft drink>lemonade; soft drink>milk; soft drink>mineral water; soft drink>obesity; soft drink>sugar; soft drink>supermarket; soft drink>tax; soft drink>tea; soft drink>water; software>concept; software>data; software>hard drive; software>information; software>logic; software>programmer; software>spreadsheet; software>television; software>video game; soil>aluminium; soil>atmosphere; soil>bacteria; soil>desert; soil>dirt; soil>drought; soil>earth; soil>erosion; soil>fat; soil>geology; soil>iron; soil>lead; soil>oxygen; soil>salt; soil>sand; soil>solution; soil>virus; soldier>army; soldier>endurance; soldier>police officer; soldier>profession; solicitor>advocate; solicitor>court; solicitor>lawyer; solicitor>salesman; solidarity>tribe; solitude>anxiety; solitude>creativity; solitude>illusion; solitude>loneliness; solitude>pirate; solitude>privacy; solitude>time; solution>air; solution>carbon dioxide; solution>chemistry; solution>concentration; solution>gas; solution>gold; solution>liquid; solution>mixture; solution>oil; solution>oxygen; solution>pressure; solution>salt; solution>steel; solution>sugar; solution>temperature; solution>water; son>boy; son>daughter; son>family; son>inheritance; son>law; son>male; son>man; son>parent; son>reproduction; song>author; song>choir; song>composer; song>concert; song>music; song>opera; song>orchestra; song>piano; song>poetry; song>radio; song>rhythm; song>singer; song>singing; soul>angel; soul>consciousness; soul>disability; soul>dream; soul>emotion; soul>essence; soul>heart; soul>heaven; soul>hell; soul>intelligence; soul>life; soul>materialism; soul>matter; soul>mind; soul>motivation; soul>paradise; soul>paraphrase; soul>psychologist; soul>psychology; soul>reason; soul>self; soul>self-awareness; soul>sense; soul>spirit; sound>air; sound>atmosphere; sound>bird; sound>communication; sound>density; sound>drum; sound>ear; sound>earth; sound>earthquake; sound>fire; sound>frog; sound>gas; sound>human; sound>liquid; sound>mammal; sound>microphone; sound>music; sound>pressure; sound>radio; sound>rain; sound>ratio; sound>sense; sound>species; sound>steel; sound>telephone; sound>temperature; sound>water; sound>wave; sound>wind; soundtrack>album; soundtrack>book; soundtrack>film; soundtrack>music; soundtrack>science fiction; soundtrack>video game; soup>alphabet; soup>bean; soup>beef; soup>bread; soup>butter; soup>carrot; soup>cheese; soup>chicken; soup>coconut; soup>cod; soup>crab; soup>cream; soup>cucumber; soup>dessert; soup>fish; soup>flour; soup>food; soup>grain; soup>immigration; soup>juice; soup>leek; soup>lemon; soup>liquid; soup>meat; soup>milk; soup>mushroom; soup>onion; soup>pasta; soup>peanut; soup>pineapple; soup>potato; soup>pottery; soup>refugee; soup>restaurant; soup>rice; soup>ritual; soup>salt; soup>spice; soup>tomato; soup>turkey; soup>water; soup>vegetable; soup>vinegar; soup>yogurt; south>adjective; south>adverb; south>earth; south>east; south>geography; south>map; south>north; south>noun; south>west; souvenir>clothing; souvenir>gift; souvenir>hat; souvenir>memory; souvenir>mug; souvenir>notebook; souvenir>pin; souvenir>postcard; souvenir>poster; souvenir>tourism; souvenir>t-shirt; souvenir>architecture; space>bucket; space>circle; space>dimension; space>distance; space>earth; space>experiment; space>farming; space>force; space>geography; space>hunting; space>knowledge; space>measurement; space>metre; space>observation; space>ownership; space>perception; space>philosopher; space>physics; space>property; space>psychology; space>radio; space>second; space>spectrum; space>sphere; space>surface; space>temperature; space>time; space>water; spade>beach; spade>blade; spade>gardening; spade>tool; spam>cholesterol; spam>protein; spam>vitamin; spark>electrician; specialist>expert; species>animal; species>bacteria; species>biology; species>bird; species>deer; species>dna; species>essence; species>fish; species>gene; species>genetics; species>giraffe; species>god; species>human; species>insect; species>life; species>lion; species>mammal; species>offspring; species>pig; species>plant; species>reproduction; species>reptile; spectrum>ghost; spectrum>rainbow; speculation>currency; speculation>investor; speculation>risk; speculation>stock; speech>brain; speech>cancer; speech>consonant; speech>culture; speech>human; speech>language; speech>lung; speech>name; speech>nerve; speech>psychologist; speech>psychology; speech>singing; speech>speculation; speech>vocabulary; speech>vowel; speed>aircraft; speed>bullet; speed>distance; speed>earth; speed>length; speed>matter; speed>metre; speed>planet; speed>slope; speed>time; speed>walk; spelling>word; spelling>writing; sphere>angle; sphere>ball; sphere>circle; sphere>dimension; sphere>earth; sphere>kilogram; sphere>volume; spice>antibiotic; spice>bark; spice>fruit; spice>garlic; spice>herb; spice>leaf; spice>perfume;

spice>root; spice>salt; spice>seed; spice>species; spice>vegetable; spider>ant; spider>banana; spider>bee; spider>blood; spider>goat; spider>habitat; spider>insect; spider>instinct; spider>kidney; spider>mammal; spider>milk; spider>momentum; spider>oxygen; spider>parachute; spider>plant; spider>predator; spider>protein; spider>sex; spider>silks; spider>space; spider>strobe; spider>taste; spider>wasp; spider>virus; spider>vitamin; spinach>broccoli; spinach>copper; spinach>fruit; spinach>iron; spinach>leaf; spinach>plant; spinach>protein; spinach>seed; spirit>angel; spirit>belief; spirit>blood; spirit>body; spirit>breath; spirit>consciousness; spirit>essence; spirit>existence; spirit>experience; spirit>force; spirit>ghost; spirit>god; spirit>hierarchy; spirit>intellect; spirit>intelligence; spirit>law; spirit>life; spirit>mind; spirit>monster; spirit>personality; spirit>psychology; spirit>religion; spirit>soul; spirit>writing; spite>economy; spite>psychology; spokesman>spokesperson; spokesperson>journalism; spokesperson>president; spoon>brass; spoon>cutlery; spoon>diamond; spoon>fork; spoon>hammer; spoon>ice cream; spoon>liquid; spoon>plastic; spoon>rice; spoon>silver; spoon>soup; spoon>sugar; spoon>tin; sport>boxing; sport>chess; sport>childhood; sport>competition; sport>cycling; sport>education; sport>gambing; sport>illustration; sport>salary; sport>sponsorship; sport>television; sport>tennis; sport>wage; spouse>bride; spouse>gender; spouse>husband; spouse>marriage; spouse>wife; spread>spreadsheet; spreadsheet>asset; spreadsheet>calculation; spreadsheet>chart; spreadsheet>currency; spreadsheet>data; spreadsheet>database; spreadsheet>error; spreadsheet>exchange rate; spreadsheet>finance; spreadsheet>formula; spreadsheet>fraud; spreadsheet>logic; spreadsheet>percentage; spreadsheet>professor; spreadsheet>risk; spreadsheet>space; squad>army; squad>soldier; square>angle; square>area; square>rectangle; stable>barn; stable>building; stable>cow; stable>horse; stadium>baseball; stadium>basketball; stadium>concert; stadium>cricket; stadium>sport; stadium>steel; stadium>turkey; staff>employment; stage>feeling; stage>theatre; stain>art; stain>bacteria; stain>bronze; stain>heat; stain>ironing; stain>laundry; stain>paint; stain>wood; staircase>stairs; stairs>air; stairs>balcony; stairs>child; stairs>escalator; stairs>fire; stairs>ladder; stairs>safety; stairs>specification; stairs>wheelchair; stamina>endurance; stand>stadium; star>arab; star>civilization; star>concentration; star>density; star>earth; star>energy; star>fuel; star>iron; star>kilogram; star>kilometre; star>light; star>metre; star>oxygen; star>photograph; star>planet; star>radiation; star>regulation; star>second; star>sun; star>x-ray; starvation>death; starvation>famine; starvation>farmer; starvation>fat; starvation>food; starvation>hunger; starvation>muscle; starvation>poverty; starvation>seed; starvation>vitamin; state>government; station>bus station; station>police station; station>post office; statistic>data; statistic>statistics; statistics>bias; statistics>chemistry; statistics>computer; statistics>data; statistics>experiment; statistics>geography; statistics>prediction; statistics>research; statue>life; statue>memorial; statue>monument; statue>sculpture; status symbol>book; status symbol>cigarette; status symbol>commerce; status symbol>fashion; status symbol>jeans; status symbol>mansion; status symbol>scar; status symbol>turkey; status>city; status>status symbol; steak>grill; steak>meat; steak>salmon; steak>sheep; steak>tuna; steam>agriculture; steam>air; steam>electricity; steam>mist; steam>water; steam>volume; steel>aluminium; steel>bridge; steel>building; steel>clock; steel>construction; steel>copper; steel>cutlery; steel>density; steel>earth; steel>iron; steel>knife; steel>mining; steel>oil; steel>oxygen; steel>plastic; steel>scrap; steel>sculpture; steel>ship; steel>surgery; steel>tin; steel>tool; steel>train; steel>washing machine; steel>water; steel>wire; steering wheel>aircraft; steering wheel>boat; steering wheel>button; steering wheel>height; steering wheel>remote control; steering wheel>ship; steering wheel>steel; steering wheel>vehicle; step>walk; stereotype>advertising; stereotype>art; stereotype>chess; stereotype>cliché; stereotype>competition; stereotype>crime; stereotype>discrimination; stereotype>disposition; stereotype>feedback; stereotype>gang; stereotype>gun; stereotype>literature; stereotype>mobile phone; stereotype>motivation; stereotype>narrative; stereotype>obesity; stereotype>party; stereotype>prejudice; stereotype>reality; stereotype>recruitment; stereotype>self-esteem; stereotype>sympathy; stereotype>video game; stick>branch; stimulus>concept; stimulus>perception; stock market>auction; stock market>gambing; stock market>investment; stock market>profession; stock market>stock; stock>bank; stock>business; stock>copper; stock>corporation; stock>debt; stock>individual; stock>investment; stock>loan; stock>monopoly; stock>ownership; stock>stock market; stock>volunteer; stocking>analogy; stocking>clothing; stocking>cotton; stocking>linen; stocking>silk; stocking>skirt; stocking>sock; stockings>tights; stocking>wool; stomach>animal; stomach>aspirin; stomach>bacteria; stomach>bird; stomach>brain; stomach>digestion; stomach>fat; stomach>insect; stomach>mammal; stomach>muscle; stomach>protein; stop>bus stop; stop>full stop; storage>warehouse; store>retail; storey>apartment; storey>architect; storey>basement; storey>building; storey>ceiling; storey>floor; storey>height; storey>house; storey>loft; storey>parking; storey>roof; storey>soil; storey>street; storey>agriculture; storm>carbon dioxide; storm>desert; storm>disaster; storm>dust; storm>earth; storm>god; storm>hall; storm>lightning; storm>ocean; storm>rain; storm>rainforest; storm>salt; storm>ski; storm>skiing; storm>snow; storm>snowboarding; storm>soil; storm>thunder; storm>thunderstorm; storm>tornado; storm>wave; storm>wind; story>narrative; story>soap opera; story>storey; strands>beach; strap>baggage; strap>cloth; strap>clothing; strap>fabric; strap>leather; strap>paper; strap>plastic; strap>ribbon; strap>rope; strap>steel; strap>watch; strap>wrist; strategy>plan; straw>cereal; straw>concrete; straw>construction; straw>cucumber; straw>grain; straw>mushroom; straw>paper; straw>rice; straw>shoe; straw>strawberry; straw>wheat; strawberry>apple; strawberry>berry; strawberry>chocolate; strawberry>cream; strawberry>dessert; strawberry>fruit; strawberry>ice cream; strawberry>pie; strawberry>plant; strawberry>sugar; strawberry>turkey; strawberry>world; stream>cave; stream>desert; stream>erosion; stream>fish; stream>floor; stream>habitat; stream>lake; stream>ocean; stream>rain; stream>river; stream>snow; stream>thunderstorm; stream>waterfall; stream>wildlife; street>brick; street>building; street>café; street>civilization; street>commerce; street>concrete; street>culture; street>economics; street>grass; street>motorway; street>nation; street>parking; street>pedestrian; street>restaurant; street>road; street>soil; street>transport; street>transportation; street>tree; strength>courage; strength>persuasion; strength>willpower; strength>virtue; stretch>baseball; strike>cricket; strike>washing machine; string>kite; string>rope; string>runway; stroke>anxiety; stroke>aspirin; stroke>bacteria; stroke>brain; stroke>cancer; stroke>fat; stroke>headache; stroke>heart; stroke>obesity; stroke>pain; stroke>pharmacist; stroke>self-esteem; stroke>skin; stroke>virtual reality; structure>architecture; structure>art; structure>atom; structure>biology; structure>building; structure>column; structure>construction; structure>data; structure>engineering; structure>hierarchy; structure>infrastructure; structure>observation; structure>organization; structure>pattern; structure>philosophy; structure>population; structure>science; structure>snow; structure>system; student>album; student>college; student>learning; student>lecture; student>politician; student>primary school; student>secondary school; student>tutor; student>university; studio>animation; studio>architecture; studio>artist; studio>corporation; studio>dancer; studio>employee; studio>music; studio>painting; studio>photography; studio>pottery; studio>radio; studio>sculpture; studio>university; studio>workshop; study>education; study>experiment; study>research; stupidity>comedy; stupidity>common sense; stupidity>factory; stupidity>genius; stupidity>idiot; stupidity>ignorance; stupidity>intelligence; stupidity>reason; stupidity>understanding; stupidity>wit; style>design; style>fashion; substance>drug; substance>matter; suburb>apartment; suburb>storey; suburb>tram; success>failure; success>goal; success>success; sufferer>suffering; suffering>abuse; suffering>anger; suffering>anxiety; suffering>confusion; suffering>contempt; suffering>cruelty; suffering>disappointment; suffering>disgust; suffering>doubt; suffering>embarrassment; suffering>empathy; suffering>envy; suffering>evil; suffering>fear; suffering>frustration; suffering>grief; suffering>happiness; suffering>hate; suffering>health care; suffering>hell; suffering>human rights; suffering>hunger; suffering>hygiene; suffering>insurance; suffering>irritation; suffering>jealousy; suffering>loneliness; suffering>medicine; suffering>mercy; suffering>pain; suffering>panic; suffering>pity; suffering>pleasure; suffering>punishment; suffering>remorse; suffering>resentment; suffering>sadness; suffering>safety; suffering>security; suffering>shame; suffering>suicide; suffering>sympathy; suffering>terrorism; suffering>thirst; suffering>torture; suffering>war; suffering>violence; suffix>adjective; suffix>adverb; suffix>comparative; suffix>plural; suffix>prefix; suffix>superlative; sugar>alcohol; sugar>ant; sugar>dessert; sugar>dna; sugar>honey; sugar>ice cream; sugar>junk food; sugar>obesity; sugar>slavery; sugar>water; suggestion>psychology; suicide>adaptation; suicide>death; suicide>debt; suicide>dna; suicide>grief; suicide>homelessness; suicide>immune system; suicide>insomnia; suicide>liberty; suicide>patient; suicide>peer pressure; suicide>prejudice; suicide>sin; suicide>war; suitcase>linen; suitcase>luggage; suitcase>wheel; suitcase>wool; summer>autumn; summer>baseball; summer>beach; summer>cricket; summer>hail; summer>rain; summer>season; summer>skateboarding; summer>surfing; summer>television; summer>tennis; summer>thunderstorm; summer>turkey; summer>winter; summit>volleyball; summit>erosion; summit>hill; summit>mountain; summit>synonym; sun>air; sun>astronomy; sun>carbon; sun>carbon dioxide; sun>carbon monoxide; sun>earth; sun>energy; sun>gas; sun>gold; sun>green; sun>horizon; sun>iron; sun>light; sun>metre; sun>oxygen; sun>parachute; sun>philosopher; sun>planet; sun>pupil; sun>pyramid; sun>radiation; sun>sky; sun>spectrum; sun>star; sun>sunlight; sun>sunrise; sun>sunset; sun>telescope; sun>theory; sun>wave; sun>week; sun>weight; sun>x-ray; sunday>century; sunday>club; sunday>god; sunday>headquarters; sunday>magazine; sunday>monday; sunday>newspaper; sunday>park; sunday>public transport; sunday>radio; sunday>red; sunday>saturday; sunday>sun; sunday>week; sunday>weekend; sunglasses>actor; sunglasses>atmosphere; sunglasses>beach; sunglasses>blindness; sunglasses>celebrity; sunglasses>court; sunglasses>film; sunglasses>glass; sunglasses>gold; sunglasses>hospital; sunglasses>metal; sunglasses>mirror; sunglasses>plastic; sunglasses>slang; sunglasses>sunlight; sunglasses>surfing; sunglasses>windsurfing; sunlight>atmosphere; sunlight>beach; sunlight>cap; sunlight>cloud; sunlight>coal; sunlight>curtain; sunlight>daylight; sunlight>dna; sunlight>earth; sunlight>garden; sunlight>helmet; sunlight>horizon; sunlight>leisure; sunlight>light; sunlight>moonlight; sunlight>painting; sunlight>park; sunlight>photography; sunlight>planet; sunlight>season; sunlight>sun; sunlight>sunglasses; sunlight>swimming pool; sunlight>wall; sunrise>dawn; sunrise>day; sunrise>daylight; sunrise>horizon; sunrise>morning; sunrise>noon; sunrise>spectrum; sunrise>sun; sunrise>sunset; sunset>astronomy; sunset>atmosphere; sunset>dawn; sunset>earth; sunset>east; sunset>horizon; sunset>light; sunset>oxygen; sunset>sun; sunset>sunrise; sunset>west; sunshine>sunlight; superiority>superior; superlative>adjective; superlative>adverb; superlative>comparative; superlative>grammar; superlative>greatness; supermarket>bakery; supermarket>bank; supermarket>book; supermarket>brand; supermarket>bread; supermarket>cereal; supermarket>cigarette; supermarket>clothing; supermarket>coffee; supermarket>country; supermarket>department store; supermarket>fish; supermarket>flour; supermarket>flower; supermarket>food; supermarket>fruit; supermarket>infrastructure; supermarket>juice; supermarket>laundry; supermarket>luggage; supermarket>magazine; supermarket>meat; supermarket>medicine; supermarket>milk; supermarket>newspaper; supermarket>pet; supermarket>petrol station; supermarket>pharmacy; supermarket>produce; supermarket>province; supermarket>rice; supermarket>soft drink; supermarket>suburb; supermarket>sugar; supermarket>tea; supermarket>tobacco; supermarket>toy; supermarket>vegetable; supervision>regulation; supervision>supervisor; supervisor>budget; supervisor>recruitment; supervisor>title; supper>dinner; supper>milk; supplier>manufacturing; support>sympathy; supporter>alphabet; supporter>cathedral; supporter>missile; surface>angle; surface>ball; surface>distance; surface>earth; surface>engineering; surface>physics; surface>sphere; surfing>ocean; surfing>recreation; surfing>shark; surfing>shore; surfing>skateboarding; surfing>snowboarding; surfing>windsurfing; surgeon>dentist; surgeon>medicine; surgeon>miss; surgeon>mr; surgeon>mrs; surgeon>surgery; surgery>bone; surgery>brain; surgery>dentist; surgery>disease; surgery>hospital; surgery>infection; surgery>injury; surgery>laser; surgery>medication; surgery>medicine; surgery>pain; surgery>patient; surgery>robot; surgery>suffering; surgery>surgeon; surname>hyphen; surname>preposition; surname>synonym; surroundings>energy; surroundings>geography; surroundings>matter; surroundings>proximity; survival>life; suspect>arrest; suspect>crime; suspect>criminal; suspect>judge; suspect>prosecutor; suspense>anxiety; suspense>conflict; suspense>hero; suspense>literature; suspense>mystery; suspense>psychologist; suspense>psychology; suspense>terror; suspense>waiter; sustainability>agriculture; sustainability>atmosphere; sustainability>capitalism; sustainability>carbon; sustainability>civilization; sustainability>climate; sustainability>climate change; sustainability>coal; sustainability>commodity; sustainability>crime; sustainability>earth; sustainability>ecology; sustainability>economics; sustainability>economy; sustainability>energy; sustainability>environmentalist; sustainability>extinction; sustainability>fair; sustainability>fat; sustainability>food; sustainability>forest; sustainability>fruit; sustainability>global warming; sustainability>industry; sustainability>lake; sustainability>law; sustainability>longevity; sustainability>market; sustainability>material; sustainability>meat; sustainability>obesity; sustainability>ocean; sustainability>oxygen; sustainability>population; sustainability>price; sustainability>recycling; sustainability>river; sustainability>science; sustainability>society; sustainability>sun; sustainability>technology; sustainability>transport; sustainability>war; sustainability>water; sustainability>weather; sustainability>vegetable; sustainability>woodland; swan>animal; swan>bird; swan>duck; swan>extinction; swan>species; sweater>button; sweater>cotton; sweater>ice hockey; sweater>jacket; sweater>shirt; sweater>sleeve; sweater>t-shirt; sweater>wool; sweater>youth; sweatshirt>sweater; swimming pool>bacteria; swimming pool>basement; swimming pool>basketball; swimming pool>beach; swimming pool>circle; swimming pool>concrete; swimming pool>department store; swimming pool>disability; swimming pool>disease; swimming pool>diving; swimming pool>fountain; swimming pool>hotel; swimming pool>infant; swimming pool>insect; swimming pool>iron; swimming pool>metal; swimming pool>oxygen; swimming pool>park; swimming pool>plastic; swimming pool>pump; swimming pool>recreation; swimming pool>rectangle; swimming pool>skateboarding; swimming pool>supermarket; swimming pool>toddler; swimming pool>toy; swimming pool>tv; swimming pool>virus; swimming pool>yard; switch>brass; switch>copper; switch>design; switch>electrician; switch>electronics; switch>glass; switch>metal; switch>plastic; switch>steel; sword>blade; sword>bronze; sword>combat; sword>copper; sword>god; sword>history; sword>iron; sword>literature; sword>martial art; sword>parade; sword>shield; sword>steel; sword>turkey; sword>umbrella; sword>uniform; syllable>consonant; syllable>language; syllable>poetry; syllable>rhyme; syllable>word; syllable>vowel; syllabus>communication; syllabus>curriculum; syllabus>education; syllabus>exam; syllabus>grammar; syllabus>professor; syllabus>training; symbol>entity; symbol>history; symbol>icon; symbol>idea; symbol>learning; symbol>logo; symbol>punctuation; symbol>uniform; sympathy>empathy; symptom>blindness; symptom>diagnosis; symptom>disease; symptom>engineer; symptom>rash; synonym>adjective; synonym>adverb; synonym>noun; synonym>preposition; system>concrete; system>culture; system>economics; system>engineering; system>institution; system>market; system>person; system>physics; system>property; system>reasoning; system>reasoning; system>society; system>structure; table tennis>friction; table tennis>gram; table tennis>sport; tablet>notebook; tail>animal; tail>bird; tail>body; tail>cat; tail>deer; tail>dog; tail>emotion; tail>feather; tail>fish; tail>fly;

traffic>bicycle; traffic>bus; traffic>lane; traffic>law; traffic>parking; traffic>pedestrian; traffic>roundabout; traffic>rush hour; traffic>traffic jam; traffic>traffic light; traffic>vehicle;
tragedy>composer; tragedy>culture; tragedy>dance; tragedy>definition; tragedy>destiny; tragedy>dignity; tragedy>drama; tragedy>elite; tragedy>fear; tragedy>goat; tragedy>god;
tragedy>law; tragedy>luck; tragedy>male; tragedy>narrative; tragedy>opera; tragedy>paradox; tragedy>person; tragedy>erosion; tragedy>pity; tragedy>poetry; tragedy>reversal; tragedy>ritual;
tragedy>society; tragedy>structure; tragedy>suffering; trail>autumn; trail>bridge; trail>climbing; trail>cycling; trail>erosion; trail>horse; trail>lane; trail>road; trail>running; trail>ski;
trail>snow; trail>soldier; trail>wheelchair; trail>woodland; train>airport; train>bicycle; train>cargo; train>coal; train>food; train>machine; train>money; train>passenger; train>praise;
train>public transport; train>redevelopment; train>ship; train>tram; train>truck; train>vehicle; train>wheel; trainee>college; trainee>university; training>artificial
intelligence; training>capacity; training>career; training>college; training>combat; training>education; training>employment; training>feedback; training>goal; training>knowledge;
training>learning; training>profession; training>religion; training>ritual; training>robot; training>skill; training>tool; training>war; train>bus; tram>cab; tram>cargo; tram>concrete;
tram>infrastructure; tram>noise; tram>specification; tram>spy; tram>wheelchair; translation>accuracy; translation>actor; translation>adaptation; translation>ambiguity;
translation>artist; translation>business; translation>chemistry; translation>communication; translation>concept; translation>culture; translation>devil; translation>dictionary;
translation>film; translation>grammar; translation>idiom; translation>language; translation>literature; translation>music; translation>musician; translation>novel; translation>novelist;
translation>opera; translation>perfection; translation>physics; translation>poet; translation>poetry; translation>rhyme; translation>science; translation>technology;
translation>theatre; translation>vocabulary; translation>word; translation>writing; transport>action; transport>airport; transport>beer; transport>boat; transport>bridge; transport>bus;
transport>bus station; transport>cable; transport>canal; transport>carbon dioxide; transport>cargo; transport>cattle; transport>city; transport>coal; transport>concrete;
transport>construction; transport>debt; transport>dirty; transport>education; transport>electronics; transport>escalator; transport>fashion; transport>ferry; transport>global warming;
transport>globalization; transport>government; transport>helicopter; transport>horse; transport>human; transport>infrastructure; transport>lake; transport>landing; transport>leisure;
transport>machine; transport>ocean; transport>passenger; transport>pedestrian; transport>pressure; transport>public transport; transport>railway; transport>recreation;
transport>risk; transport>river; transport>road; transport>rocket; transport>roundabout; transport>running; transport>sea; transport>ship; transport>skiing; transport>smog;
transport>soil; transport>steam; transport>steel; transport>street; transport>tax; transport>team; transport>technology; transport>tourism; transport>trade; transport>trail;
transport>train; transport>tram; transport>truck; transport>walking; transport>warehouse; transport>water; transport>vehicle; transport>wheel; transport>village; transport>wind;
transport>wool; transportation>transport; trash>junk food; trash>litter; trash>waste; travel>bicycle; travel>boat; travel>bus; travel>culture; travel>cycling; travel>exploration;
travel>holiday; travel>itinerary; travel>passport; travel>pedestrian; travel>people; travel>public transport; travel>recreation; travel>refugee; travel>research; travel>safety;
travel>tourism; travel>trade; travel>train; travel>transport; travel>walking; travel>van; travel>vehicle; tray>photography; tray>plastic; tray>rectangle; treasure>motivation;
treasure>pirate; treasure>protagonist; treasure>war; treat>threat; treat>treaty; treatment>therapy; treaty>constitution; treaty>contract; treaty>signature; treaty>slavery; treaty>torture;
tree>apple; tree>banana; tree>barbecue; tree>bark; tree>carbon; tree>carbon dioxide; tree>chocolate; tree>construction; tree>drought; tree>fruit; tree>fuel; tree>god;
tree>habitat; tree>paper; tree>pine; tree>plant; tree>rainforest; tree>species; tree>tea; tree>wood; tree>woodland; trek>trekking; trekking>transport; trekking>walking;
trend>business; trend>culture; trend>fashion; trend>population; trend>technology; trial>appeal; trial>authority; trial>crime; trial>government; trial>innocence; trial>judge;
trial>jury; trial>law; trial>prosecution; triangle>angle; triangle>architect; triangle>astronomy; triangle>circle; triangle>construction; triangle>dimension; triangle>earthquake;
triangle>nature; triangle>rectangle; triangle>shape; triangle>sphere; tribe>archaeology; tribe>civilization; tribe>leadership; tribe>nation; tribe>civilization; tribute>hostage;
tribute>philosophy; tribute>province; tribute>subsidy; tribute>war; trilogy>fantasy; trilogy>fiction; trilogy>literature; trilogy>novel; trilogy>science fiction; trilogy>video game; trip>injury;
trip>tourism; trip>travel; trophy>animal; trophy>boxing; trophy>hunting; trophy>medal; trophy>silver; trophy>television; trouble>challenge; trouble>risk; trousers>baseball;
trousers>caif; trousers>clothing; trousers>cotton; trousers>denim; trousers>dress; trousers>fashion; trousers>hip; trousers>history; trousers>jeans; trousers>shirt; trousers>shorts;
trousers>skateboarding; trousers>skirt; trousers>underpants; trousers>underwear; trousers>waist; truck>carbon dioxide; truck>cargo; truck>engine; truck>global warming;
truck>steel; truck>ton; truck>water; truck>wheel; trumpet>army; trumpet>brass; trumpet>harmony; trumpet>orchestra; trumpet>rectangle; truth>belief; truth>concept;
truth>contradiction; truth>debate; truth>disposition; truth>envy; truth>essence; truth>existence; truth>fact; truth>gender; truth>god; truth>imagination; truth>information;
truth>inquiry; truth>intelligence; truth>judgment; truth>knowledge; truth>law; truth>lie; truth>logic; truth>mirror; truth>philosophy; truth>proposition; truth>reality; truth>reason;
truth>religion; truth>science; truth>sense; truth>time; truth>understanding; t-shirt>advertising; t-shirt>black; t-shirt>clothing; t-shirt>ink; t-shirt>ironing; t-shirt>laundry; t-
shirt>marketing; t-shirt>shirt; t-shirt>souvenir; t-shirt>vest; t-shirt>yellow; tube>surfing; tube>television; tuesday>election; tuesday>monday; tuesday>pink; tuesday>saint;
tuesday>wednesday; tuna>dolphin; tuna>extinction; tuna>oil; tuna>predator; tuna>protein; tuna>shark; tuna>species; tuna>whale; tune>melody; tunnel>canal; tunnel>carbon
monoxide; tunnel>coal; tunnel>firefighter; tunnel>flood; tunnel>mining; tunnel>roof; tunnel>tool; tunnel>traffic; tunnel>turkey; tunnel>weapon; turkey>democracy; turkey>helicopter;
turkey>recession; turkey>republic; turkey>tank; turkey>volcano; turn>turning; turnover>revenue; tutor>classroom; tutor>education; tutor>lecturer; tutor>professional; tutor>secondary
school; tutor>seminar; tutor>student; tutor>teaching; tv>television; twin>brain; twin>cat; twin>cattle; twin>deer; twin>dog; twin>genetics; twin>heart; twin>liver; twin>offspring;
twin>pregnancy; twin>psychology; twin>sheep; twin>sibling; umbrella>cotton; umbrella>priest; umbrella>procession; umbrella>slang; umbrella>steel; umbrella>stomach;
umbrella>temple; umbrella>tent; uncertainty>certainty; uncertainty>economics; uncertainty>engineering; uncertainty>error; uncertainty>finance; uncertainty>gaming;
uncertainty>game; uncertainty>insurance; uncertainty>philosophy; uncertainty>physics; uncertainty>probability; uncertainty>psychology; uncertainty>risk; uncertainty>statistics;
uncertainty>weather forecast; uncle>aunt; uncle>brother; uncle>brother-in-law; uncle>family; uncle>parent; underpants>brand; underpants>button; understanding>anxiety;
understanding>awareness; understanding>brain; understanding>concept; understanding>electronics; understanding>engineering; understanding>explanation;
understanding>knowledge; understanding>language; understanding>message; understanding>perception; understanding>person; understanding>prediction;
understanding>psychiatrist; understanding>science fiction; understanding>thought; undertaking>company; unemployment>debt; unemployment>disability;
unemployment>globalization; unemployment>homelessness; unemployment>inflation; unemployment>percentage; unemployment>productivity; unemployment>recession;
unemployment>self-esteem; unemployment>training; unemployment>xenophobia; uniform>air force; uniform>airline; uniform>bank; uniform>brand; uniform>clothing;
uniform>employer; uniform>health care; uniform>hotel; uniform>organization; uniform>police; uniform>post office; uniform>prison; uniform>restaurant; uniform>retailer;
uniform>school; uniform>shirt; uniform>skirt; uniform>trousers; union>alliance; union>apartment; unit>statistics; university>astronomy; university>engineering;
university>grammar; university>laboratory; university>logic; university>music; university>religion; university>research; university>science; university>seminar; unrest>rebellion;
unrest>riot; upgrade>software; usage>grammar; usage>language; user>consumer; vaccination>bacteria; vaccination>cancer; vaccination>cow; vaccination>immune system;
vaccination>infection; vaccination>protein; vaccination>vaccine; vaccination>virus; vaccine>antibiotic; vaccine>dna; vaccine>human; vaccine>immune system; vaccine>infection;
vaccine>liberty; vaccine>medication; vaccine>protein; wage>employee; wage>employer; wage>employment; wage>salary; waist>beauty; waist>beauty; waist>fat; waist>hip;
waist>jewellery; waist>obesity; waist>rib; validity>argument; validity>contradiction; validity>logic; walk>walking; walker>pedestrian; walking>anxiety; walking>bone; walking>cancer;
walking>concentration; walking>cycling; walking>endurance; walking>exercise; walking>hand; walking>health; walking>hobby; walking>human; walking>knee; walking>learning;
walking>memory; walking>nature; walking>obesity; walking>pedestrian; walking>public transport; walking>robot; walking>running; walking>sheep; walking>stroke; walking>trout;
walking>transport; wall>air; wall>architecture; wall>ceiling; wall>city; wall>fence; wallet>cash; wallet>copper; wallet>credit card; wallet>denim; wallet>exercise; wallet>fabric;
wallet>handbag; wallet>hotel; wallet>id card; wallet>itinerary; wallet>leather; wallet>paper; wallet>passport; wallet>pocket; wallet>shoe; wallet>travel;
valley>agriculture; valley>castle; valley>cliff; valley>climate; valley>earth; valley>erosion; valley>flood; valley>geography; valley>geology; valley>river; valley>stream;
valley>sunlight; valley>temperature; valley>waterfall; valley>village; van>airport; van>ambulance; van>car; van>hotel; van>parking; van>truck; van>vehicle; vandalism>abuse;
vandalism>beauty; vandalism>crime; vandalism>criminal; vandalism>gang; vandalism>history; vandalism>imprisonment; vandalism>life; vandalism>mayor;
vandalism>monument; vandalism>punishment; vandalism>riot; vanity>death; vanity>god; vanity>image; vanity>justice; vanity>pride; vanity>selfishness; vanity>woman; war>ant;
war>common sense; war>deception; war>democracy; war>failure; war>famine; war>inheritance; war>market; war>peace; war>revenge; war>society; war>treaty; war>violence;
ward>hospital; wardrobe>castle; wardrobe>chest of drawers; wardrobe>clothes; wardrobe>cupboard; wardrobe>oak; wardrobe>palace; wardrobe>tray; warehouse>airport;
warehouse>computer; warehouse>database; warehouse>customs; warehouse>manufacturer; warehouse>preservation; warehouse>railway; warehouse>transport; warmth>heat;
warrior>combat; warrior>courage; warrior>faith; warrior>honour; warrior>loyalty; warrior>mercy; warrior>rebellion; warrior>soldier; warrior>terrorism; warrior>tribe; warrior>war;
warrior>virtue; vase>flower; washing machine>bacteria; washing machine>carbon dioxide; washing machine>clothing; washing machine>clutch; washing machine>housewife;
washing machine>inventor; washing machine>ironing; washing machine>laundry; washing machine>machine; washing machine>pillow; washing machine>pump; washing
machine>swimming pool; washing machine>water; wasp>animal; wasp>ant; wasp>bee; wasp>butterfly; wasp>genetics; wasp>hair; wasp>head; wasp>hierarchy; wasp>honey;
wasp>insect; wasp>sex; wasp>species; wasp>spider; waste>air; waste>awareness; waste>education; waste>litter; waste>material; waste>pollution; waste>recycling; waste>soil;
waste>sustainability; waste>university; waste>water; watch>alarm; watch>art; watch>clock; watch>computer; watch>department store; watch>digital camera; watch>gold;
watch>temperature; watch>time; watch>video game; water>acid; water>agriculture; water>atmosphere; water>atom; water>bacteria; water>biology; water>body; water>canal;
water>carbon dioxide; water>climate; water>cloud; water>coal; water>commerce; water>cooking; water>day; water>density; water>desert; water>diving; water>dna; water>dolphin;
water>drought; water>earth; water>energy; water>erosion; water>fire; water>fish; water>flood; water>fog; water>fountain; water>fuel; water>gas; water>gram; water>hail;
water>household; water>human; water>hygiene; water>ice; water>ice hockey; water>ice skating; water>iceberg; water>industry; water>kilogram; water>kitchen; water>lake;
water>life; water>liquid; water>litre; water>mineral water; water>mist; water>mountain; water>oil; water>oxygen; water>ozone; water>plant; water>politics; water>pollution;
water>pond; water>pregnancy; water>protein; water>pump; water>rain; water>rainbow; water>river; water>sea; water>shower; water>sink; water>skiing; water>snow;
water>snowboarding; water>soil; water>solution; water>steam; water>stream; water>sugar; water>sun; water>sunlight; water>surfing; water>sweat; water>tide; water>toilet;
water>travel; water>valley; water>vegetation; water>whale; water>volcano; waterfall>iceberg; waterfall>volcano; wave>distance; wave>energy; wave>light; wave>momentum;
wave>phenomenon; wave>physics; wave>sound; wave>water; wave>violin; wave>x-ray; way>road; weakness>acid; weakness>brain; weakness>nerve; wealth>agriculture;
wealth>archaeology; wealth>asset; wealth>building; wealth>business; wealth>castle; wealth>cathedral; wealth>clothing; wealth>economics; wealth>human; wealth>income;
wealth>industrialization; wealth>inheritance; wealth>investment; wealth>leadership; wealth>money; wealth>ownership; wealth>ownership; wealth>pension; wealth>poverty; wealth>property;
wealth>resource; wealth>soil; wealth>temple; wealth>war; wealth>word; weapon>aircraft; weapon>bracelet; weapon>copper; weapon>crime; weapon>gun; weapon>helicopter;
weapon>horse; weapon>hunting; weapon>knife; weapon>missile; weapon>rocket; weapon>sail; weapon>ship; weapon>sword; weapon>tank; weapon>war; weather>atmosphere;
weather>building; weather>chemical; weather>climate; weather>climate change; weather>earth; weather>erosion; weather>famine; weather>flood; weather>fog; weather>hail;
weather>heat; weather>ice; weather>lake; weather>plant; weather>potential; weather>snow; weather>storm; weather>sun; weather>sunlight; weather>thunderstorm;
weather>tornado; web page>database; web page>image; web page>website; web page>video; webcam>company; webcam>computer; webcam>daycare; webcam>laptop;
webcam>manufacturing; webcam>microphone; webcam>password; webcam>prison; webcam>time; webcam>web page; webcam>video clip; website>blog; website>celebrity;
website>computer; website>credit card; website>database; website>document; website>email; website>government; website>image; website>social networking; website>software;
website>stock market; website>web page; website>webcam; wedding>bride; wedding>ceremony; wedding>culture; wedding>divorce; wedding>god; wedding>groom;
wedding>judge; wedding>marriage; wedding>mosque; wedding>priest; wedding>ritual; wedding>sibling; wedding>veil; wednesday>calendar; wednesday>fish;
wednesday>meat; wednesday>slang; wednesday>sun; wednesday>thursday; wednesday>tuesday; weed>adaptation; weed>agriculture; weed>crop; weed>garden; weed>grain;
weed>insect; weed>lawn; weed>park; weed>plant; weed>soil; week>february; week>fortnight; week>month; weekday>friday; weekday>monday; weekday>thursday;
weekday>timetable; weekday>tuesday; weekday>wednesday; weekday>week; weekday>weekend; vegetable>acid; vegetable>adjective; vegetable>broccoli; vegetable>bulb;
vegetable>cabbage; vegetable>carrot; vegetable>cereal; vegetable>cooking; vegetable>com; vegetable>courgette; vegetable>cucumber; vegetable>dessert; vegetable>fat;
vegetable>fruit; vegetable>garlic; vegetable>leek; vegetable>lettuce; vegetable>market; vegetable>meal; vegetable>mushroom; vegetable>nutrition; vegetable>onion;
vegetable>peach; vegetable>potato; vegetable>protein; vegetable>purple; vegetable>salt; vegetable>spinach; vegetable>street; vegetable>supermarket; vegetable>tomato;
vegetable>vitamin; vegetation>desert; vegetation>fire; vegetation>flood; vegetation>hierarchy; vegetation>system; vehicle>aircraft; vehicle>bicycle; vehicle>boat; vehicle>brake;
vehicle>bus; vehicle>camel; vehicle>friction; vehicle>fuel; vehicle>machine; vehicle>parachute; vehicle>ship; vehicle>train; vehicle>truck; weight>chemistry; weight>ear;
weight>fluid; weight>force; weight>kilogram; weight>matter; weight>momentum; weight>sun; veil>bride; veil>curtain; veil>face; veil>funeral; veil>mask; veil>priest; veil>sail; veil>sin;
veil>temple; vein>turkey; vein>blood; vein>carbon dioxide; vein>heart; vein>laser; vein>lung; vein>oxygen; welfare>debt; welfare>disability; welfare>disaster; welfare>famine;

welfare>household; welfare>illness; welfare>income; welfare>orphan; welfare>pension; welfare>population; welfare>poverty; welfare>salary; welfare>solidarity; welfare>tax; welfare>unemployment; welfare>veteran; welfare>widow; well-being>economics; well-being>wealth; velvets>cotton; velvets>linen; velvets>silks; velvets>wool; verb>adverb; verb>clause; verb>grammar; verb>infinitive; verb>language; verb>phrasal verb; verb>word; verdict>appeal; verdict>judgment; verdict>jury; verdict>law; verse>poetry; west>adjective; west>adverb; west>death; west>earth; west>east; west>geography; west>hunting; west>liberty; west>north; west>noun; west>south; west>sun; west>water; vet>veteran; veteran>crisis; veteran>holiday; whale>animal; whale>dolphin; whale>mammal; wheat>bacteria; wheat>beer; wheat>biscuit; wheat>bread; wheat>butterfly; wheat>cake; wheat>cereal; wheat>cookie; wheat>disease; wheat>fat; wheat>flour; wheat>immune system; wheat>iron; wheat>pancake; wheat>pasta; wheat>pastry; wheat>pie; wheat>protein; wheat>rice; wheat>tractor; wheat>turkey; wheat>vitamin; wheel>aircraft; wheel>bicycle; wheel>cattle; wheel>energy; wheel>friction; wheel>horse; wheel>iron; wheel>kilogram; wheel>metre; wheel>pottery; wheel>road; wheel>sphere; wheel>steering wheel; wheel>technology; wheel>tool; wheel>torture; wheel>transport; wheel>truck; wheel>walk; wheel>wire; wheel>wood; wheelchair>artificial intelligence; wheelchair>bicycle; wheelchair>bus; wheelchair>chair; wheelchair>computer; wheelchair>disability; wheelchair>illness; wheelchair>revenue; wheelchair>switch; wheelchair>toilet; wheelchair>tram; wheelchair>walking; whim>carriage; whisky>alcohol; whisky>coconut; whisky>corn; whisky>grain; whisky>linen; whisky>sand; whisky>wheat; whistle>basketball; whistle>dj; whistle>headache; whistle>ice hockey; whistle>police; whistle>rhythm; whistle>train; white>angel; white>autumn; white>black; white>chess; white>cloud; white>coldness; white>cotton; white>crystal; white>density; white>earth; white>frost; white>heat; white>heaven; white>ice; white>innocence; white>life; white>light; white>milk; white>peace; white>polar bear; white>racist; white>science; white>snow; white>sun; white>sunlight; white>swan; white>tiger; white>toothpaste; white>vinegar; white>winter; white>virtue; vice>alcohol; vice>anger; vice>deputy; vice>envy; vice>faith; vice>gambling; vice>hated; vice>hope; vice>jealousy; vice>laziness; vice>pride; vice>sin; vice>vanity; vice>virtue; victory>aggression; victory>competition; victory>hero; victory>monster; victory>trophy; victory>war; video clip>advertising; video clip>blog; video clip>celebrity; video clip>digital camera; video clip>icon; video clip>mobile phone; video clip>television; video clip>webcam; video clip>website; video clip>video; video game>artificial intelligence; video game>distraction; video game>mud; video game>sex; video game>video; video>dvd; video>image; video>recording; video>technology; video>television; video>virtual reality; widow>marriage; widow>orphan; width>length; view>opinion; wife>bride; wife>crime; wife>divorce; wife>education; wife>female; wife>husband; wife>marriage; wife>mother; wife>mrs; wife>profession; wife>sin; wife>spouse; wife>surname; wife>wedding; wife>widow; wife>woman; wilderness>camping; wilderness>climate change; wilderness>commerce; wilderness>earth; wilderness>forest; wilderness>genetics; wilderness>geology; wilderness>global warming; wilderness>human; wilderness>hunting; wilderness>industrialization; wilderness>laboratory; wilderness>law; wilderness>mountain; wilderness>nature; wilderness>privilege; wilderness>recreation; wilderness>science; wilderness>species; wilderness>summer; wilderness>technology; wilderness>zoo; wildlife>eagle; wildlife>ecology; wildlife>education; wildlife>extinction; wildlife>feather; wildlife>fishing; wildlife>habitat; wildlife>nature; wildlife>rabbit; wildlife>recreation; wildlife>shark; wildlife>sport; wildlife>tiger; wildlife>traffic; village>cathedral; village>city; village>community; village>election; village>elite; village>farmer; village>god; village>island; village>market; village>mayor; village>mosque; village>neighbourhood; village>rice; village>sheep; village>starvation; village>suburb; village>town; villager>newspaper; willing>will; willpower>self-control; willpower>self-discipline; win>victory; wind>aircraft; wind>cattle; wind>civilization; wind>coast; wind>cold; wind>desert; wind>dust; wind>east; wind>electricity; wind>erosion; wind>fat; wind>feather; wind>friction; wind>history; wind>human; wind>insect; wind>island; wind>kite; wind>landscape; wind>mountain; wind>ocean; wind>penguin; wind>predator; wind>recreation; wind>runway; wind>sail; wind>sailing; wind>sheep; wind>soil; wind>speed; wind>storm; wind>sun; wind>temperature; wind>thunderstorm; wind>tornado; wind>transport; wind>water; wind>weather; wind>weed; wind>west; wind>windsurfing; wind>winter; wind>world; window>aircraft; window>bus; window>curtain; window>door; window>fire; window>lead; window>paper; window>radiation; window>roof; window>steel; window>wall; window>vehicle; window>wood; windsurfing>helmet; windsurfing>kite; windsurfing>sail; windsurfing>snowboarding; windsurfing>surfing; wine>acid; wine>archaeologist; wine>beer; wine>cancer; wine>carbon dioxide; wine>carbon footprint; wine>cucumber; wine>dentist; wine>fence; wine>gardener; wine>grape; wine>grape; wine>litre; wine>oak; wine>plant; wine>plastic; wine>poetry; wine>rice; wine>rose; wine>species; wine>spice; wine>sugar; wine>sweet; wine>wall; wine>vine; vinegar>acid; vinegar>apple; vinegar>beer; vinegar>cabbage; vinegar>champagne; vinegar>cholesterol; vinegar>dessert; vinegar>fever; vinegar>food; vinegar>garlic; vinegar>herb; vinegar>honey; vinegar>onion; vinegar>pear; vinegar>rice; vinegar>spice; vinegar>tomato; vinegar>water; vinegar>wheat; vinegar>wine; wing>aircraft; wing>bat; wing>bird; wing>flight; wing>fluid; wing>gas; wing>helicopter; wing>liquid; wing>penguin; wing>physics; wing>surface; wing>tree; winner>champion; winter>butterfly; winter>global warming; winter>snow; winter>aggression; violence>archaeology; violence>capitalism; violence>dignity; violence>human rights; violence>interest; violence>law; violence>mammal; violence>murder; violence>neglect; violence>philosophy; violence>police; violence>pride; violence>psychology; violence>respect; violence>shame; violence>suicide; violence>terrorism; violence>trade; violence>war; violin>arch; violin>cello; violin>disco; violin>fraud; violin>guitar; violin>horse; violin>jazz; violin>leather; violin>orchestra; violin>piano; violin>oak; violin>rhythm; violin>silks; violin>silver; violin>spectrum; violin>wood; wire>brass; wire>bronze; wire>cable; wire>copper; wire>diamond; wire>electricity; wire>gold; wire>iron; wire>lead; wire>monopoly; wire>silver; wire>steel; virtual reality>machine; virtual reality>navy; virtual reality>science fiction; virtual reality>simulation; virtual reality>techno; virtual reality>therapy; virtue>blame; virtue>courage; virtue>courtesy; virtue>dignity; virtue>discipline; virtue>duty; virtue>faith; virtue>generosity; virtue>goodness; virtue>happiness; virtue>honesty; virtue>hope; virtue>humility; virtue>intelligence; virtue>justice; virtue>kindness; virtue>law; virtue>love; virtue>loyalty; virtue>mercy; virtue>patience; virtue>peace; virtue>praise; virtue>principle; virtue>psychology; virtue>respect; virtue>serenity; virtue>solitude; virtue>sympathy; virtue>truth; virtue>turkey; virtue>vice; virtue>wisdom; virus>animal; virus>antibiotic; virus>bacteria; virus>cancer; virus>carbon dioxide; virus>crystal; virus>disease; virus>dna; virus>evolution; virus>genetics; virus>infection; virus>insect; virus>life; virus>plant; virus>poison; virus>protein; virus>species; virus>vaccination; virus>vaccine; wisdom>analogy; wisdom>artificial intelligence; wisdom>consciousness; wisdom>empathy; wisdom>experience; wisdom>human; wisdom>ignorance; wisdom>imitation; wisdom>intelligence; wisdom>knowledge; wisdom>memory; wisdom>philosophy; wisdom>poison; wisdom>psychology; wisdom>reflection; wisdom>science fiction; wisdom>self-awareness; wisdom>sincerity; wisdom>turkey; wisdom>verb; wisdom>wisdom; wish>fiction; wish>goal; wish>common sense; wit>genius; wit>humour; wit>poetry; wit>reasoning; vitality>health; vitality>life; vitality>youth; vitamin>bone; vitamin>disease; vitamin>fat; vitamin>grain; vitamin>hygiene; vitamin>lemon; vitamin>liver; vitamin>meat; vitamin>milk; vitamin>morale; vitamin>mouse; vitamin>nutrient; vitamin>nutrition; vitamin>protein; vitamin>rat; vitamin>rice; vitamin>salt; vitamin>skin; vitamin>sunlight; vitamin>surgeon; vitamin>water; withdraw>anxiety; withdraw>headache; witness>credibility; witness>judge; witness>lawyer; witness>memory; witness>prosecution; witness>prosecutor; witness>sense; vocabulary>collocation; vocabulary>communication; vocabulary>education; vocabulary>gesture; vocabulary>infant; vocabulary>language; vocabulary>learning; vocabulary>speech; volcano>carbon; volcano>carbon dioxide; volcano>carbon monoxide; volcano>chemical; volcano>climate; volcano>famine; volcano>landscape; volcano>ozone; volcano>planet; volcano>radiation; volcano>soil; volcano>sun; volleyball>basketball; volleyball>tennis; volume>area; volume>centimetre; volume>circle; volume>density; volume>formula; volume>gas; volume>length; volume>liquid; volume>litre; volume>pressure; volume>quantity; volume>sphere; volume>teaspoon; volume>weight; woman>adult; woman>beauty; woman>biology; woman>birth; woman>birthday; woman>breast; woman>child; woman>cigarette; woman>copper; woman>economics; woman>engineering; woman>female; woman>gene; woman>genetics; woman>girl; woman>graduate; woman>health; woman>historian; woman>human; woman>lady; woman>matter; woman>mirror; woman>professional; woman>psychology; woman>science; woman>spirit; woman>suicide; wood>aluminium; wood>bark; wood>branch; wood>cherry; wood>coconut; wood>extract; wood>fuel; wood>leaf; wood>oak; wood>pine; wood>root; wood>ski; wood>soil; wood>weapon; woodland>forest; woodland>grass; wool>auction; wool>carpet; wool>clothing; wool>cotton; wool>leather; wool>linen; wool>protein; wool>sheep; wool>silks; wool>skin; word>adjective; word>adverb; word>bear; word>clause; word>grammar; word>language; word>noun; word>phrase; word>preposition; word>pronoun; word>pronunciation; word>speech; word>verb; word>writing; workaholic>alcohol; workaholic>alcoholic; workaholic>stroke; worker>workforce; workforce>employment; workforce>industry; workforce>management; workforce>wage; workplace>corporation; workplace>employment; workplace>factory; workplace>office; workplace>organization; workshop>aircraft; workshop>building; workshop>factory; workshop>machine; workshop>manufacturing; workshop>tool; world>career; world>civilization; world>concept; world>consumer; world>country; world>devil; world>earth; world>experience; world>globalization; world>heaven; world>hell; world>history; world>human; world>paradise; world>planet; world>population; world>reality; world>region; world>science fiction; world>temptation; worm>animal; worm>corpse; worm>dog; worm>insect; worm>leg; worm>snake; worm>soil; worm>species; worry>anxiety; worry>emotion; worry>exercise; worry>hug; worry>mind; worry>risk; worry>sleep; worship>angel; worship>celebrity; worship>flag; worship>god; worship>religion; worship>saint; worship>soiety; worst>superlative; wound>bacteria; wound>bandage; wound>blood; wound>bruise; wound>bullet; wound>infection; wound>injury; wound>knife; wound>razor; wound>skin; vow>ceremony; vow>promise; vow>wedding; vow>win; vow>witness; vowel>alphabet; vowel>consonant; vowel>curtain; vowel>jaw; vowel>language; vowel>preposition; vowel>sound; vowel>syllable; voyage>exploration; voyage>travel; wrinkle>dog; wrinkle>skin; wrinkle>water; wrist>hand; writer>actor; writer>argument; writer>astronomy; writer>author; writer>biology; writer>blog; writer>court; writer>culture; writer>dialogue; writer>diary; writer>edition; writer>education; writer>entertainment; writer>essay; writer>film; writer>fraud; writer>greed; writer>historian; writer>idea; writer>image; writer>irony; writer>literature; writer>logic; writer>lyrics; writer>narrative; writer>novel; writer>paper; writer>parliament; writer>philosophy; writer>physics; writer>poetry; writer>policy; writer>politics; writer>religion; writer>revelation; writer>rhyme; writer>rhythm; writer>science fiction; writer>society; writer>writing; writing>alphabet; writing>author; writing>communication; writing>essay; writing>gerund; writing>history; writing>human; writing>illustration; writing>information; writing>journalism; writing>journalist; writing>language; writing>literacy; writing>literature; writing>novelist; writing>painting; writing>paper; writing>pen; writing>pencil; writing>poet; writing>science; writing>syllable; writing>time; writing>translation; writing>writer; xenophobia>concept; xenophobia>culture; xenophobia>imitation; xenophobia>immigration; xenophobia>individual; xenophobia>prejudice; xenophobia>propaganda; xenophobia>racism; xenophobia>society; x-ray>aluminium; x-ray>astronomy; x-ray>bone; x-ray>cancer; x-ray>copper; x-ray>dna; x-ray>energy; x-ray>experiment; x-ray>iron; x-ray>kilogram; x-ray>life; x-ray>muscle; x-ray>surgeon; yacht>air conditioning; yacht>aluminium; yacht>boat; yacht>cargo; yacht>customs; yacht>radio; yacht>sailing; yacht>ship; yacht>steel; yacht>tide; yard>area; yard>golf; yard>inch; yard>length; yard>metre; yard>volume; year>archaeology; year>astronomy; year>autumn; year>calendar; year>day; year>daylight; year>dinosaur; year>earth; year>geology; year>hour; year>millennium; year>minute; year>month; year>pie; year>planet; year>season; year>second; year>summer; year>sun; year>time; year>weather; year>week; year>vegetation; year>winter; year>yellow>autumn; year>yellow>bee; year>yellow>bus; year>yellow>butter; year>yellow>coward; year>yellow>curiosity; year>yellow>daylight; year>yellow>electricity; year>yellow>envy; year>yellow>friendship; year>yellow>gold; year>yellow>green; year>yellow>hope; year>yellow>imagination; year>yellow>intellectual; year>yellow>jam; year>yellow>jealousy; year>yellow>laser; year>yellow>lemon; year>yellow>mirror; year>yellow>optimism; year>yellow>rebellion; year>yellow>recreation; year>yellow>rose; year>yellow>spectrum; year>yellow>spice; year>yellow>star; year>yellow>sugar; year>yellow>summer; year>yellow>sun; year>yellow>sunshine; year>yellow>temperature; year>yellow>traffic light; year>yellow>wasps; year>yellow>water; year>yellow>vein; yoga>mind; yoga>soul; yoga>stroke; yogurt>bacteria; yogurt>bakery; yogurt>camel; yogurt>cherry; yogurt>cucumber; yogurt>farmer; yogurt>fast food; yogurt>fat; yogurt>fruit; yogurt>garlic; yogurt>goat; yogurt>honey; yogurt>jam; yogurt>mango; yogurt>milk; yogurt>olive; yogurt>onion; yogurt>peach; yogurt>pineapple; yogurt>protein; yogurt>salt; yogurt>sheep; yogurt>spinach; yogurt>strawberry; yogurt>sugar; yogurt>turkey; youngster>child; youth>adult; youth>childhood; youth>obesity; youth>suicide; zebra>animal; zebra>donkey; zebra>extinction; zebra>hill; zebra>horse; zebra>mammal; zebra>mountain; zebra>species; zebra>woodland; zone>tv; zoo>bird; zoo>chicken; zoo>ecology; zoo>elephant; zoo>extinction; zoo>fish; zoo>giraffe; zoo>insect; zoo>mammal; zoo>neglect; zoo>reptile; zoo>species; zoo>whale;

Appendix AD

As discussed in Subchapter 11.2, this listing shows in respect to English Vocabulary Profile for each vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each language ability level. For each observed vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from A1 to A1&A2&B1&B2&C1&C2.

In contrast with Appendix AE, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

<p>Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1 (i.e. when range of language ability levels reached so far is A1)</p> <p><i>Alltogether 248 nouns with the following subdivision.</i></p> <p><i>Nouns belonging to language ability level A1 (248 nouns):</i> adult; afternoon; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; body; book; box; boy; bread; breakfast; bus; business; butter; café; cake; camera; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; coat; coffee; colour; computer; conversation; country; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; door; dress; drink; dvd; ear; email; evening; eye; face; factory; family; farm; father; february; film; fish; floor; flower; food; foot; football; friday; friend; fruit; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; kitchen; knife; language; leg; lesson; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mrs; mum; museum; music; nationality; newspaper; night; noise; nose; note; november; number; october; paint; paper; parent; park; party; pen; pencil; people; person; pet; picnic; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; skirt; smoking; snow; son; soup; sport; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; thursday; time; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;</p> <p><i>Nouns belonging to language ability level A2 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level B1 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level B2 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level C1 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level C2 (0 nouns):</i> No nouns.</p>
<p>Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2 (i.e. when range of language ability levels reached so far is A1-A2)</p> <p><i>Alltogether 706 nouns with the following subdivision.</i></p> <p><i>Nouns belonging to language ability level A1 (265 nouns):</i> adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; kitchen; knife; language; leg; lesson; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; party; pen; pencil; people; person; pet; phone; photo; picnic; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;</p> <p><i>Nouns belonging to language ability level A2 (441 nouns):</i> accident; actor; adjective; adverb; advertisement; air; airport; alarm clock; album; alcohol; ambulance; apartment; area; art; artist; aunt; autumn; bag; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; bottle; bowl; boyfriend; brain; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; chat; chef; chemist; chemistry; cheque; chess; chicken; cigarette; circle; cleaner; climbing; cloud; clown; club; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson;</p>

granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; island; jam; jazz; jewellery; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; mail; main course; make-up; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; monkey; mosque; motorway; mountain; mouse; mp3 player; music; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; perfume; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; stage; stairs; star; steak; stomach; storm; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour guide; tourist; towel; toy; traffic; traffic light; tram; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (0 nouns):
No nouns.

Nouns belonging to language ability level B2 (0 nouns):
No nouns.

Nouns belonging to language ability level C1 (0 nouns):
No nouns.

Nouns belonging to language ability level C2 (0 nouns):
No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1 (i.e. when range of language ability levels reached so far is A1-B1)

Alltogether 1374 nouns with the following subdivision.

Nouns belonging to language ability level A1 (273 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; fam; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; party; pen; pencil; people; person; pet; photo; photo; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (465 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; bottle; bowl; boyfriend; brain; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pence; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (636 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collection; comedy; comma; common sense; communication; competitor; complaint; conclusion; conference; consonant; contest; continent; contract; corn; cottage; cotton; cough; count; courgette; court; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cyclist; death; definite article; demand; description; design; designer; destination; detective; diagram; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; dust; dustbin; duty; duvet; earth; economics; education; effect; effort; elbow; election; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; essay; event; exchange; exchange rate; excitement; exhibition; experience; experiment; expert; explanation; extreme sports; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; figure; fire station; firefighter; firework; firm; flag; flood; flour; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; heart attack; heat; heater; heel; height; herb; hero; honeymoon; hope; hostel; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; membership; mess; message board; metal; mile; millimetre; mind; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; olive; opinion; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; password; patient; pattern; pay; pea; peace; peach; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; religion; relation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; return; review; robot; role; roll; rose; rubbish; rug; rule; run; salon; salary; salmon; sand; sandal; saucer; scene; scenery; science fiction; scientist; sculpture; season; secondary school; secret; security; seller; sense; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; silence; silk; sir; ski; skin; sleep; sleeve; smile; smoke; soap opera; social networking; society; soldier; solution; south; souvenir; speech; speed; spice; spider; spinach; spy; statue; step; stick; stone; strawberry; stream; strike; studio; study; style; success; sunrise; sunset; sunshine; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thought; throat; thumb; thunder; tick; tiger; tin; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; unit; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windscreens; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; zone;

Nouns belonging to language ability level B2 (0 nouns):
No nouns.

Nouns belonging to language ability level C1 (0 nouns):

No nouns.

Nouns belonging to language ability level C2 (0 nouns):
No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2 (i.e. when range of language ability levels reached so far is A1-B2)

Altogether 2121 nouns with the following subdivision.

Nouns belonging to language ability level A1 (280 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (473 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; famer; fashion; fast food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pence; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; policeman; police station; policeman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; room; rock; roof; roundabout; rubber; rugby; ruler; runner; running; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; shirt; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; super; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; term; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (682 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; captain; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; demand; description; design; designer; destination; detective; diagram; difficulty; direction; dirt; disadvantage; disappearance; discount; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; equipment; essay; event; exchange; exchange rate; excitement; exhibition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; figure; fire station; firefighter; firework; firm; flag; flood; flour; flute; fly; folk; food; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hole; honeymoon; hope; honest; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; mix; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; oil; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; patient; pattern; pay; pea; peace; peach; peak; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; religion; relation; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; reward; reward; robot; role; roll; rose; rubbish; rug; rule; run; sailor; salary; salmon; sand; sandal; saucerpan; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; silence; silk; sir; ski; skill; skin; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spice; spider; spinach; spy; statue; step; stick; stone; strawberry; stream; strike; studio; study; style; success; suggestion; sum; sunrise; sunset; sunshine; support; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thief; thought; throat; thumb; thunder; tick; tiger; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windscreens; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (686 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; atom; attachment; attempt; authority; availability; award; backup; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breed; brick; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; chart; chemical; cherry; chest; chimney; choir; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confidence; confirmation; confusion; consciousness; consequence; consideration; construction; consultant; consumer; container; content; contribution; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; error; escalator; estate; evidence; evil; evolution; exclamation mark; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fault; feather; feedback; female; fence; finance; fingernail; first language; fisherman; flame; flash; fluency; grade; fortune; fox; freedom; frost; frustration; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graphite; graph; grove; greatness; grief; growth; guarantee; guidance; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; honesty; honour; hom; host; household; human rights; humour; hunting; hyphen; icon; idiom; idiot; image; immigrant; income; independence; individual; infection; inflation; injury; input; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; invasion; inventor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leek; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; love; loss; loyalty; lung; lungs; majority; male; management; mankind; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; microphone; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience;

pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; poison; polar bear; policy; politeness; pond; popularity; portrait; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; production; professional; proof; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punishment; quarrel; query; quiet; racism; rage; rainbow; rape; rate; razor; reach; reality; recession; recovery; recreation; referee; reference; reflection; refugee; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush hour; sadness; safety; satellite; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shooting; shopkeeper; shot; sickness; signal; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storey; strategy; stronger; string; stroke; structure; substance; suburb; suffering; suffix; suicide; sunlight; supplier; surface; surgery; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; target; task; teaspoon; telecommunications; telescope; temper; temptation; terminal; terms; terrace; terror; terrorism; terrorist; theft; theory; therapy; thermometer; thesis; thigh; thirst; threat; tide; timing; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; trophy; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; wheat; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (0 nouns):
No nouns.

Nouns belonging to language ability level C2 (0 nouns):
No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2&C1 (i.e. when range of language ability levels reached so far is A1-C1)

Alltogether 2470 nouns with the following subdivision.

Nouns belonging to language ability level A1 (281 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; fam; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (479 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bad; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; church; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; gas; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; field; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guest; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; home; housewife; ice; id card; idea; information; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motoway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pence; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; pin; plant; plastic; playground; plural; police; police officer; police station; policewoman; policeman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweets; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; type; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Nouns belonging to language ability level B1 (694 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; captain; care; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; demand; description; design; designer; destination; detective; diagram; diet; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; equipment; essay; event; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; figure; fire station; firefighter; firework; firm; flag; flood; flour; flu; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; honeymoon; hope; hostel; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; improvement; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; mind; minimum; mix; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; olive; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; passport; patient; pattern; pay; pea; peace; peach; peak; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; registration; relation; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; return; reward; review; robot; role; roll; rose; row; rubbish; rug; rule; run; sailor; salary; salesman; salmon; sand; sandal; saucerpan; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; silence; silk; single; sir; ski; skill; skin; sleep; lease; smell; smile; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spice; spider; spinach; spy; statue; step; stick; stone; store; strawberry; stream; strike; studio; study; style; success; suggestion; sum; sunset; sunset; sunshine; support; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thief; thought; throat; thumb; thunder; tick; tiger; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tub; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (701 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; assistance; atom; attachment; attempt; authority; availability; award; backup; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breakthrough; breed; brick; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint;

carbon monoxide; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; chart; chemical; cherry; chest; chimney; choir; citizen; civilization; daim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; combination; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confidence; confirmation; confusion; consciousness; consequence; consideration; construction; consultant; consumer; container; content; contribution; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; bed; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; error; escalator; estate; evidence; evil; evolution; exclamation mark; exhaustion; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fate; fault; feather; feedback; female; fence; finance; fingernail; first language; fisherman; flame; flash; fluency; force; fortune; fox; freedom; frost; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graduate; graph; grave; greatness; grief; growth; guarantee; guidance; guilt; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; honesty; honour; horn; host; household; human rights; humour; hunting; hyphen; icon; idiom; idiot; image; immigrant; income; independence; individual; infection; inflation; injury; input; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; invasion; inventor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leek; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; loaf; loss; loyalty; lung; lyrics; majority; male; management; mankind; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; microphone; mine; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; network; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience; pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pint; pitch; pity; planning; plumber; poison; polar bear; politics; politeness; pond; popularity; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; production; professional; proof; proposal; protection; protest; psychologist; psychology; publication; publicity; publisher; punning; punishment; quarrel; query; quiet; racism; rage; rainbow; rape; rate; razor; reach; reality; rebel; recession; recovery; recreation; referee; reference; reflection; refugee; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush hour; sadness; safety; satellite; savings; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shooting; shopkeeper; shot; sickness; signal; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storey; strategy; strength; string; structure; substance; subub; suffering; suffix; suicide; sunlight; supplier; surface; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; target; task; teaspoon; telecommunications; telescope; temper; temptation; terminal; terms; terrace; terror; terrorism; terrorist; theft; theme; theory; therapy; thermometer; thesis; thigh; thirst; threat; tide; time; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; trophy; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; wheat; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (315 nouns):

abortion; acceptance; adaptation; administration; aggression; aid; allegation; allowance; amateur; amendment; angle; annoyance; appetite; applause; archaeologist; archaeology; asset; assumption; assurance; auction; audition; awareness; bacteria; beak; blindness; boundary; brass; bribe; bronze; carriage; cholesterol; clutch; coal; collaboration; commodity; competence; complex; component; consent; constitution; consumption; contestant; controversy; corruption; coverage; cultivation; daycare; dedication; deficiency; delegate; density; deodorant; destiny; diesel; digestion; discomfort; discrimination; disorder; disrespect; disruption; dissertation; distraction; distress; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; erosion; establishment; evaluation; exaggeration; exhaust; exhibit; expenses; exploration; exposure; extinction; fabric; fairness; feast; fibre; formula; friction; fright; fund; funding; gadget; gain; garment; gene; generalization; genius; geology; gerund; gesture; globalization; greed; habit; harassment; hate; hatred; hazard; health care; historian; hospitality; housing; humanity; hygiene; iceberg; illustration; import; indication; industrialization; infrastructure; injustice; innocence; innovation; insight; inspection; installation; interaction; isolation; itinerary; jargon; jealousy; joint; journal; junk; knob; labour; landmark; launch; lawn; leadership; liability; limitation; literacy; log; logic; loneliness; lounge; machinery; magistrate; mammal; mansion; mat; mechanism; miner; mining; mode; move; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; nutrition; obesity; obstacle; occurrence; odds; organ; overdraft; ownership; ozone; panel; paradise; pastry; peasant; pensioner; perfection; personnel; phenomenon; pony; praise; predator; pregnancy; premises; principle; privilege; probability; productivity; programmer; progression; proposition; prostitute; protein; provider; pulse; pyramid; radiation; rating; ratio; rebellion; recruitment; rectangle; redevelopment; register; reign; relevance; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rival; role model; rudeness; runaway; sack; sacrifice; saint; saving; scholar; sector; self; self-esteem; selfishness; sequence; serial; setback; sewing; shame; shuttle; language; shyness; side effect; simplicity; simulation; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; spam; specification; spectrum; speculation; sphere; spokesman; spokesperson; sponsorship; staircase; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; strip; subsidy; subtitles; successor; summit; supervision; supervisor; surgeon; takeover; tank; teamwork; technician; techno; telly; therapist; tobacco; torture; trainee; transportation; trek; tuition; turnover; uncertainty; usage; walker; warrior; vegetation; veil; vein; well-being; vest; win; wine; wit; witch; workforce; workplace; workshop; youngster;

Nouns belonging to language ability level C2 (0 nouns):

No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2&C1&C2 (i.e. when range of language ability levels reached so far is A1-C2)

Alltogether 2878 nouns with the following subdivision.

Nouns belonging to language ability level A1 (283 nouns):

adult; afternoon; age; animal; answer; apple; april; am; august; baby; bag; ball; banana; band; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; block; bottom; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; doctor; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (483 nouns):

accident; actor; adjective; adventure; adverb; advertisement; advice; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; colleague; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; field; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guest; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; home; housewife; ice; id card; idea; information; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; pac; pear; perfume; petrol; petrol station; photon; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rug; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; singular; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; tune; type; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Nouns belonging to language ability level B1 (706 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; background; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breathe; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage;

cabin; cable; calculator; calf; camel; camp; campsites; canal; cancer; candidate; candle; captain; care; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; credit; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; delivery; demand; description; design; designer; destination; detail; detective; diagram; diet; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; equipment; essay; event; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; fight; figure; fire station; firefighter; firework; firm; flag; flood; flour; flu; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grid; groom; ground; guard; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hole; honeymoon; hope; hostel; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; importance; improvement; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jump; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lower; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; mind; minimum; mix; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northeast; northwest; novel; object; ocean; officer; olive; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; passport; patient; pattern; pay; pea; peace; peach; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; registration; relation; relaxation; religion; remote control; repair; reply; reporter; request; rescue; rescuer; resort; respect; result; return; reward; review; robot; role; roll; rose; row; rubbish; rug; rule; run; sailor; salary; salesman; salmon; sand; sandal; saucepan; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; signpost; silence; silk; single; sir; ski; skin; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spice; spider; spinach; spy; stall; statue; step; stick; stone; store; strawberry; stream; strike; studio; student; style; success; suggestion; sum; sunrise; sunset; sunshine; support; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; temple; tent; thief; thought; throat; thumb; thunder; tick; tiger; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; union; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; vet; whale; wheelchair; video clip; wildlife; windscreen; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (718 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; assistance; atom; attachment; attempt; authority; availability; award; backup; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breakthrough; breed; brick; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; camp; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; carelessness; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; charm; chart; chemical; cherry; chest; chimney; choir; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; combination; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confession; confidence; confirmation; conflict; confusion; consciousness; consequence; conservation; consideration; construction; consultant; consumer; container; content; contribution; control; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; error; escalator; estate; evidence; evil; evolution; exclamation mark; exhaustion; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fate; fault; feather; feedback; female; fence; fighting; finance; fingernail; first language; fisherman; flame; flash; fluency; force; fortune; fox; freedom; frog; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graduate; graph; grave; greatness; grief; growth; guarantee; guidance; guilt; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; hold; honesty; honour; horn; host; household; human rights; humour; hunting; hyphen; icon; identity; idiom; idiot; image; immigrant; income; independence; individual; infection; injury; input; inspector; institution; institute; insurance; intension; intelligence; intention; invasion; inventor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; kingdom; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leek; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; load; loaf; loss; loyalty; lung; lyrics; majority; male; management; mankind; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; mention; microphone; mine; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; network; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience; pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; poison; polar bear; policy; politeness; pond; popularity; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; production; professional; proof; proposal; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punishment; quarrel; query; quiet; racism; rain; rainbow; rape; rate; razor; reach; reality; rebel; recession; recovery; recreation; referee; reference; reflection; refugee; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; room; rope; rumour; rush hour; sadness; safety; satellite; savings; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shelter; shooting; shopkeeper; shot; sickness; signal; similarity; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storage; storey; strategy; strength; string; stroke; structure; substance; suburb; suffering; suffix; suicide; sunlight; supplier; surface; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; tale; target; task; teaspoon; telecommunications; telescope; temper; temptation; tension; terminal; terms; terrace; terror; terrorism; terrorist; theft; theme; theory; therapy; thermometer; thesis; thigh; thirst; threat; tide; timing; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; wheat; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (328 nouns):

abortion; acceptance; adaptation; administration; aggression; aid; allegation; allowance; amateur; amendment; angle; annoyance; appetite; applause; archaeologist; archaeology; asset; assumption; assurance; auction; audition; awareness; bacteria; beak; blindness; boundary; brass; bribe; bronze; campaign; carriage; cholesterol; clutch; coal; collaboration; commodity; competence; complex; component; consent; constitution; consumption; contestant; controversy; convention; corruption; coverage; cultivation; daycare; dedication; deficiency; delegate; density; deodorant; deputy; destiny; diesel; digestion; discomfot; discrimination; disorder; disrespect; disruption; dissertation; distraction; distress; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; erosion; establishment; evaluation; exaggeration; exhaust; exhibit; expenses; exploration; exposure; extinction; fabric; fairness; feast; fibre; formula; friction; fright; fund; funding; gadget; gain; garment; gene; generalization; genius; geology; gerund; gesture; globalization; greed; habitat; harassment; hate; hatred; hazard; heading; health care; historian; hospitality; housing; humanity; hygiene; idol; illustration; import; indication; industrialization; infrastructure; initiative; injustice; innocence; innovation; insight; inspection; installation; integration; interaction; isolation; itinerary; jargon; jealousy; joint; journal; junk; knob; labour; landmark; launch; laws; leadership; liability; limitation; literacy; log; logic; loneliness; lounge; machinery; magistrate; mansion; mat; mechanism; miner; mining; mode; move; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; nutrition; obesity; obstacle; occurrence; odds; optimist; organ; overdraft; ownership; ozone; panel; paradise; pastry; peasant; pensioner; perfection; personnel; phenomenon; pony; praise; predator; pregnancy; premises; preservation; principle; privilege; probability; productivity; programmer; progression; prosperity; prostitute; protein; provider; pulse; purity; pyramid; radiation; rank; rating; ratio; rebellion; recruitment; rectangle; redevelopment; register; reign; relevance; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rival; role model; rudeness; runaway; sack; sacrifice; saint; saving; scholar; scholarship; sector; self; self-esteem; selfishness; sequence; serial; setback; sewing; shuttle; shyness; side effect; simplicity; simulation; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; spam; specification; spectrum; speculation; sphere; spokesman; spokesperson; sponsorship; staircase; stamina; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; strip; subsidy; subtitles; successor; summit; superior; supervision; supervisor; surgeon; takeover; tank; teamwork; technician; techno; telly; therapist; tobacco; torture; trainee; transportation; trek; tuition; turnover; uncertainty; unity; usage; walker; warrior; vegetation; veil; vein; well-being; vest; win; vine; wit; witch; workforce; workplace; workshop; youngster;

Nouns belonging to language ability level C2 (360 nouns):

acre; adolescent; advocate; alcoholic; alliance; ambiguity; analogy; anchor; antibiotic; arch; army; artificial intelligence; aspiration; assault; assembly; astronomy; attribute; awe; bark; barn; bet; bias; blackmail; blend; blister; bribery; bureaucracy; burial; capitalism; cargo; casserole; casualty; catastrophe; chancellor; chapel; charisma; cheerfulness; chill; circulation; civilian; clash; cliché; coastline; coldness; combat; comeback; commander; complexion; complexity; conception; confrontation; conscience; consensus; contempt; contraception; contraceptive; contradiction; conversion; conviction; cookie; coral; core; corpse; coup; crack; crackdown; credibility; crystal; culture; deception; delegation; denial; deprivation; descendant; desperation; diagnosis; dialect; dice; dignity; diplomacy; discretion; disgust; disposable income; disposition; dispute; dna; dominance; donor; doom; doorway; drought; echo; embrace; empathy; endurance; entity; essence; exile; expenditure; explosive; fake; famine; fireplace; fist; flesh; fluid; follower; forgery; forgiveness; fragrance; fraud; frenzy; frontier; frown; gamble; glue; goodness; grain; grasp; grin; hail; heir; heritage; hesitation; hierarchy; homelessness; horizon; hostage; hostility; humility; hypocrisy; hypothesis; ignorance; illusion; imitation; immune system; impatience; implementation; impossibility; imprisonment; incentive; inclination; individuality; infancy; infant; inheritance; insecurity; insomnia; instinct; instruction; integrity; intellect; intellectual; intensity; intent; interpretation; intervention; intruder; intrusion; irony; irritation; kidney; knot; knuckle; legislation; likelihood; linen; loathing; local; loft; longevity; massacre; masterpiece; materialism; materialist; medication; melody; memorial; mercy; merger; metaphor; millennium; missile; momentum; monopoly; morale; mortality; motion; narrative; narrator; negligence; nerve; nest; nostalgia; nostril; novelty; observer; official; offspring; omission; openness; optimism; ordeal; ornament; orphan; outbreak; output; pact; paradigm; paradox; parallel; particle; pasture; patch; peer pressure; perception; persistence; persuasion; plea; pole; precedent; presumption; prey; proceedings; procession; produce; propaganda; prosecution; prosecutor; protagonist; proverb; province; proximity; psychiatrist; quest; quotation; quote; racist;

raid; rash; realm; reasoning; recognition; recollection; recruit; referendum; reform; refuge; regime; relish; remorse; representation; resemblance; resentment; residence; resignation; resilience; resistance; resolution; restraint; retailer; retreat; revelation; reversal; rhyme; ribbon; riches; ritual; rivalry; round; ruling; saddle; sail; saying; scarcity; scenario; schooling; scrap; self-assurance; self-awareness; self-control; self-discipline; self-respect; sensibility; sentiment; shield; sibling; simplification; sin; sincerity; siren; skull; slap; slaughter; snob; socialism; sorrow; spade; spark; spite; spouse; squad; stable; starvation; stimulus; strand; strap; stupidity; sufferer; superiority; suspense; sustainability; syllabus; synonym; talks; taxpayer; tenderness; thinker; threshold; throne; timber; toddler; toughness; tractor; trait; tranquility; trash; treat; treaty; tribute; trilogy; troops; undertaking; unrest; vaccination; vaccine; validity; vandalism; vanity; warehouse; weed; velvet; verdict; veteran; whim; vice; wilderness; villager; willpower; virgin; virtue; vitality; withdrawal; vocation; woodland; workaholic; worship; vow; wrinkle; xenophobia;

Appendix AE

As discussed in Subchapter 11.2, this listing shows in respect to Oxford Wordlist for each vocabulary of school levels ranging from Preparatory to Year 4 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each school level (please note that nouns were extracted from Oxford Wordlist based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile). For each observed vocabulary ranging from Preparatory to Year 4 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from Preparatory to Year 4.

In contrast with Appendix AD, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Preparatory (i.e. vocabulary of school level Preparatory)

Alltogether 505 nouns with the following subdivision.

Nouns belonging to school level Preparatory (505 nouns):

accident; aeroplane; afternoon; air; airport; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bride; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; cereal; chair; champion; chart; cheese; cherry; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; crowd; cup; cushion; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; eagle; ear; earth; electricity; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; fire; fish; fishing; flame; floor; flower; flute; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gas; gear; ghost; giraffe; girl; glove; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; headache; heart; heaven; helicopter; helmet; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; ink; island; jacket; jail; jam; jazz; jeans; juice; june; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lighter; lightning; line; lion; lounge; love; lunch; machine; magazine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; orchestra; paint; pair; palace; pancake; paper; parade; parent; park; party; pasta; patch; peace; pear; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pineapple; pink; pirate; pizza; plan; planet; playground; poison; pole; police; pond; pony; present; prince; princess; prize; professor; project; pub; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; reptile; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; runner; running; sack; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; set; shark; shed; sheep; ship; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skateboarding; skating; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; temple; tennis; tent; theatre; thought; thumb; thunder; thursday; tiger; timber; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; triangle; trip; trophy; truck; tuesday; turn; turning; tv; type; umbrella; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; vest; west; whale; wheel; whistle; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (370 nouns):

aeroplane; afternoon; ambulance; animal; apple; arm; army; art; baby; bacon; bag; ball; ballet; balloon; barbecue; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; black; blood; blue; boat; book; bottle; box; boy; bread; breakfast; brother; brush; bus; butterfly; cake; camping; can; candle; car; cash; castle; cat; cave; cereal; chair; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clown; club; cold; colour; competition; computer; concert; cookie; court; cousin; crash; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; devil; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; earth; elephant; engine; face; factory; family; farm; farmer; fat; favourite; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; hand; hat; head; headache; heart; heaven; helicopter; hero; hill; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; june; jungle; kangaroo; kick; kid; king; kitten; lake; land; leg; lemon; leopard; lettuce; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; miss; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mum; music; musical; name; neck; night; noise; number; ocean; paint; pair; palace; paper; parent; park; party; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; poison; pole; police; pond; pony; present; prince; princess; prize; pub; puppy; purple; rabbit; rain; rainbow; red; rescue; restaurant; river; road; robot; rocket; roof; room; run; runner; running; safety; salad; sand; sandwich; saturday; sauce; school; science; sea; second; set; shark; shed; sheep; ship; shop; shopping; show; shower; side; singing; sink; siren; skateboard; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spider; sport; stairs; star; storm; story; street; sugar; summer; sun; sunday; sword; system; tail; tea; teacher; team; television; tent; thought; thunder; thursday; tiger; time; today; toilet; tomato; tooth; top; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; trophy; truck; tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; village; window; winter; witch; wolf; woman; wood; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (415 nouns):

aeroplane; afternoon; air; airport; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; bread; breakfast; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; cereal; chair; champion; chart; cheese; cherry; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; court; cousin; crab; crash; crew; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; eagle; ear; earth; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; fire; fish; fishing; flame; floor; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; headache; heart; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; jam; juice; jungle; kangaroo; kick; kitten; ladder; lake; land; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; match; meal; meat; medal; medicine; metal; milk; mind; miss; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; paint; pair; palace; pancake; paper; parade; parent; park; party; pasta; patch; peace; pencil; penguin; people; person; pet; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince;

princess; prize; professor; puppy; purple; rabbit; radio; rain; rainbow; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; run; running; sack; salad; sand; sandwich; saturday; sausage; school; science; sea; second; secret; set; shark; shed; sheep; ship; shoe; shop; shopping; shower; side; singing; siren; skate; skeleton; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; stage; stairs; star; storey; storm; street; summer; sun; sunday; tail; tea; teacher; team; tent; thought; thursday; tiger; timber; time; today; toe; toilet; tooth; top; torch; town; toy; tractor; train; training; tree; triangle; trophy; truck; tuesday; turn; turning; tv; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; video; village; wind; window; winter; witch; volcano; wolf; woman; wood; world; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 3 (459 nouns):

aeroplane; afternoon; air; airport; angel; animal; ant; apple; area; arm; amy; art; august; baby; back; bacon; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bride; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; car; case; cash; castle; cat; cave; cereal; chair; champion; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; club; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; crowd; cup; dance; dancing; day; december; desert; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; mrs; mud; mug; mum; museum; music; electricity; elephant; engine; evening; face; factory; family; farm; farmer; fat; favourite; feeling; fence; ferry; finger; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gas; gear; ghost; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; heaven; helicopter; helmet; hero; hill; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; ink; island; jacket; jail; jam; jeans; juice; june; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; magazine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; mrs; mud; mug; mum; museum; music; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; pancake; paper; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; playground; pole; police; pond; pony; present; prince; princess; prize; professor; pub; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; running; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skeleton; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; tennis; tent; theatre; thought; thunder; thursday; tiger; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; traffic; trail; train; training; travel; treasure; tree; trip; trophy; truck; tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; vest; whale; wheel; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 4 (459 nouns):

accident; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; amy; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bridge; brother; brush; bus; butterfly; cake; camera; camping; can; car; case; cash; castle; cat; cave; cereal; chair; champion; cheese; cherry; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crash; crew; cricket; cross; crowd; cup; dance; dancing; day; desert; dessert; devil; diary; dinner; dinosaur; disco; dog; doll; door; dream; dress; drink; drive; duck; ear; earth; electricity; elephant; engine; evening; face; factory; fair; family; farm; fat; feeling; fence; festival; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gas; gear; ghost; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; heart; heaven; helicopter; helmet; hero; hill; hip; history; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; jam; jazz; jeans; juice; june; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; mrs; mud; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; paper; parade; parent; park; party; pasta; patch; peace; pear; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; playground; poison; pole; police; pond; pony; present; prince; princess; prize; professor; project; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; running; sack; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; tennis; tent; thought; thunder; thursday; tiger; timber; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; triangle; trip; trophy; truck; tuesday; turn; turning; tv; type; umbrella; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 1 (i.e. vocabulary of school level Year 1)

Alltogether 592 nouns with the following subdivision.

Nouns belonging to school level Preparatory (370 nouns):

aeroplane; afternoon; ambulance; animal; apple; arm; amy; art; baby; bacon; bag; ball; ballet; balloon; barbecue; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; black; blood; blue; boat; book; bottle; box; boy; bread; breakfast; brother; brush; bus; butterfly; cake; camping; can; candle; car; cash; castle; cat; cave; cereal; chair; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; down; club; cold; colour; competition; computer; concert; cookie; court; cousin; crash; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; devil; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; earth; elephant; engine; face; factory; family; farm; farmer; fat; favourite; field; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; hand; hat; head; headache; heart; heaven; helicopter; hero; hill; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; june; jungle; kangaroo; kick; kid; king; kitten; lake; leg; lemon; leopard; lettuce; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; miss; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mum; music; musical; name; neck; night; noise; number; ocean; paint; pair; palace; paper; parent; park; party; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; poison; pole; police; pond; pony; present; prince; princess; prize; pub; puppy; purple; rabbit; rain; rainbow; rectangle; red; rescue; restaurant; river; road; robot; rocket; roof; room; ruler; run; running; safety; salad; sand; sandwich; saturday; sauce; school; science; sea; second; set; shark; shed; sheep; shirt; shop; shopping; show; shower; side; singing; sink; siren; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spider; sport; stairs; star; storm; story; street; sugar; summer; sun; sunday; sword; tail; tea; teacher; team; tennis; tent; thought; thunder; thursday; tiger; time; today; toilet; tomato; tooth; top; torch; town; toy; tractor; train; training; travel; treasure; tree; triangle; trip; trophy; truck; tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; village; window; winter; witch; wolf; woman; wood; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 1 (592 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; amy; army; arrest; art; athletics; baby; bacon; bag; ball; ballet; balloon; bank; barbecue; barn; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; bee; beef; bird; birthday; biscuit; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; brand; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; button; cabin; cake; camel; camping; can; candle; car; carpet; cash; castle; cat; cave; century; cereal; chain; chair; change; chemist; chess; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; clown; club; coffee; coin; cold; collar; collection; colour; competition; complex; computer; concert; contest; cook; cookie; cooking; coral; cost; cottage; cotton; council; count; court; cousin; cow; crash; cream; creature; cricket; crime; criminal; crocodile; cross; cucumber; cup; cupboard; dad; dance; dancer; dancing; day; december; dentist; desert; designer; desk; devil; diamond; dinner; dinosaur; dirt; disco; dive; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; dump; dvd; earth; elephant; emergency; end; ending; engine; eye; face; fact; factory; fall; family; farm; farmer; fashion; fat; father; favourite; field; fire; fish; fishing; flag; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gardening; gate; gear; gentleman; ghost; gift; giraffe; girl; glass; glasses; goal; goat; god; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; haircut; hall; hammer; hand; hat; head; headache; heart; heaven; helicopter; help; hero; hill; hole; holiday; home; homework; honey; honeymoon; honour; hope; horse; hospital; hotel; hour; house; hug; hunting; iceberg; idea; information; instructor; island; jacket; jail; january; jar; jealousy; joke; joy; june; jungle; kangaroo; kick; kid; killer; king; kiss; kit; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; leaf; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; lip; living; lounge; love; lover; lunch; lunchtime; machine; man; march; market; marriage; mask; master; mat; match; matter; meal; meat; medal; medicine; memory; mess; message; metal; microphone; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mosquito; mother; motor; mountain; mouse; moustache; mouth; movie; mrs; mud; mum; murder; murderer; mushroom; music; musical; name; narrative; nature; neck; need; nest; night; noise; note; november; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; pastry; patch; pen; pencil; penguin; people; performance; person; pet; phone; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; poison; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; pub; puppy; purple; rabbit; rain; rainbow; rainforest; rat; reach; reason; recycling; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; sail; salad; sand; sandwich; saturday; sauce; school; science; sea; season; seat; second; september; set; sewing; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; snowboarding; son; song; sound; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; suitcase; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tool; tooth; toothbrush; tow; towel; town; toy; track; tractor; train; training; tram; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turkey; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; wildlife; village; window; wing; winter; witch; wolf; volleyball; woman; wood; wool; word; workshop; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (460 nouns):

adult; aeroplane; afternoon; ambulance; animal; apple; arm; amy; army; art; baby; bacon; bag; ball; balloon; barbecue; barn; basketball; bat; battle; beach; bear; bed; bedroom; bee; bird; birthday; biscuit; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cake; camel; camping; can; candle; car; carpet; cash; castle; cat; cave; chain; chair; chess; chest; chicken; chip; chocolate; circle; city; class; classroom; climbing; clothes; clown; club; coffee; cold; colour; competition; computer; contest; cook; cookie; cooking; coral; cost; cottage; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dance; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; disco; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; dvd; earth; elephant; engine; eye; face; factory; fall; family; farm; farmer; fat; favourite; field; fire; fish; fishing; flash; fly; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gardening; gate; gear; gentleman; ghost; gift; giraffe; girl; glass; glasses; goal; god; gold; golf; grass; green; grey; ground; group; guitar; gun; gymnastics; hair; haircut; hand; hat; head; headache; heart; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; iceberg; idea; information; instructor; island; jacket; jail; january; jar; jealousy; joke; joy; june; jungle; kangaroo; kick; king; kiss; kitten; knife; lady; lake; land; lawn; leaf; leg; lemon; leopard; library; life; light; lightning; line; hunting; idea; instructor; island; jacket; jail; joke; joy; jungle; kangaroo; kick; king; kiss; kitten; knife; lady; lake; land; lawn; leaf; leg; lemon; leopard; library; life; light; lightning; line;

lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; miss; monday; money; monkey; monster; morning; mother; motor; mouse; mouth; movie; mrs; mud; mum; mushroom; music; musical; name; neck; need; night; noise; november; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; person; pet; piece; pig; pink; pirate; pizza; plan; planet; playground; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rat; red; rescue; rest; restaurant; river; road; robot; rocket; roof; room; rope; round; run; running; salad; sand; sandwich; saturday; school; science; sea; seat; second; september; set; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; shower; side; silver; singing; siren; skeleton; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; stadium; stairs; stand; star; step; storm; story; strawberry; street; summer; sun; sunday; tail; tank; tea; teacher; teaching; team; tent; thought; thursday; tiger; time; toast; today; toilet; tooth; toothbrush; top; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turkey; turn; turning; tv; uncle; walk; walking; wall; war; waste; watch; water; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 3 (520 nouns):

adult; adventure; aeroplane; afternoon; animal; answer; apple; arm; army; arrest; art; baby; bacon; bag; ball; ballet; balloon; bank; barbecue; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; bee; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; brand; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; button; cabin; cake; camel; camping; can; car; carpet; cash; castle; cat; cave; cereal; chain; chair; change; cheese; chess; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; club; coffee; coin; cold; collar; collection; colour; competition; complex; computer; concert; cook; cookie; cooking; cost; cottage; cotton; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dad; dance; dancer; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; dirt; disco; dive; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; engine; eye; face; fact; factory; fall; family; farm; farmer; fashion; fat; father; favourite; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; gift; girl; glass; glasses; goal; god; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; hall; hammer; hand; hat; head; heart; heaven; helicopter; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; joke; joy; june; jungle; kangaroo; kick; king; kitten; lady; lake; land; lane; lap; laptop; lawn; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; lip; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mother; mountain; mouse; mouth; mrs; mud; mum; murder; music; name; neck; need; nest; night; noise; note; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; pastry; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; pub; puppy; purple; rabbit; rain; rainbow; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; salad; sand; sandwich; saturday; sauce; school; science; sea; season; seat; second; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; top; towel; town; toy; track; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 4 (512 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; art; baby; bacon; bag; ball; ballet; balloon; barn; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; butter; butterfly; button; cabin; cake; camping; can; car; carpet; cash; castle; cat; cave; century; cereal; chain; chair; cheese; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; clown; club; coffee; cold; collar; colour; competition; computer; concert; contest; cook; cookie; cooking; cost; cottage; court; cousin; cow; crash; cream; creature; cricket; crime; cross; cup; cupboard; dad; dance; dancer; dancing; day; desert; designer; devil; diamond; dinner; dinosaur; dirt; disco; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; emergency; engine; eye; face; fact; factory; fall; family; farm; farmer; fashion; fat; father; field; fire; fish; fishing; flash; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; girl; glass; glasses; goal; goat; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; haircut; hall; hammer; hand; hat; head; heart; heaven; helicopter; help; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; jar; joy; june; jungle; kangaroo; kick; kid; killer; king; kiss; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; leaf; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; midnight; milk; minute; miss; monday; money; monster; morning; mother; mountain; mouse; mouth; mrs; mud; mum; mosquito; mother; motor; mountain; mouse; mouth; mrs; mud; mum; murder; murderer; music; musical; name; nature; neck; need; nest; night; noise; note; number; ocean; opening; oven; paint; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; performance; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; poison; pole; police; pony; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rainforest; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; sail; salad; sandwich; saturday; sauce; school; science; sea; season; seat; second; september; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; suitcase; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; top; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 2 (i.e. vocabulary of school level Year 2)

Alltogether 749 nouns with the following subdivision.

Nouns belonging to school level Preparatory (415 nouns):

aeroplane; afternoon; air; airport; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; basketball; bat; battle; beach; bear; bed; birthday; biscuit; bit; bite; black; blood; blue; boat; body; bone; book; bottle; bowl; box; boy; bread; breakfast; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; chair; chess; chicken; chocolate; city; class; classroom; climbing; cloud; clown; cold; colour; competition; computer; cookie; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; eagle; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; fire; fish; fishing; flame; floor; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; headache; heart; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; instructor; island; jacket; jail; jam; juice; jungle; kangaroo; kick; king; kitchen; kite; kitten; ladder; lake; land; leg; lemon; leopard; lesson; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; match; meal; meat; medal; medicine; metal; milk; mind; miss; monday; monkey; monster; morning; mother; mouse; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; paint; pair; palace; pancake; paper; parade; parent; park; partner; party; pasta; patch; peacock; pencil; penguin; people; person; pet; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince; princess; prize; professor; puppy; purple; rabbit; radio; rain; rainbow; rat; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; run; running; sack; salad; sand; sandwich; saturday; sausage; school; science; sea; second; secret; set; shark; shed; sheep; ship; shoe; shop; shopping; shower; side; singing; siren; skate; skeleton; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; stage; stairs; star; storey; store; street; summer; sun; sunday; tail; tea; teacher; team; tent; thought; thursday; tiger; time; timer; time; today; toe; toilet; tooth; top; torch; town; toy; tractor; train; training; treasure; tree; triangle; trophy; truck; tuesday; turn; turning; tv; uncle; walk; walking; wall; war; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; video; village; wind; window; winter; witch; volcano; wolf; woman; wood; world; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (460 nouns):

adult; aeroplane; afternoon; ambulance; animal; apple; arm; army; art; baby; bacon; bag; ball; balloon; barbecue; barn; basketball; bat; battle; beach; bear; bed; bedroom; bee; bird; birthday; biscuit; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cake; camel; camping; can; candle; car; carpet; cash; castle; cat; cave; chain; chair; chess; chest; chicken; chip; chocolate; circle; city; class; classroom; climbing; clothes; clown; club; coffee; cold; colour; competition; computer; contest; cook; cookie; cooking; coral; cost; cottage; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dance; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; disco; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; dvd; earth; elephant; engine; eye; face; factory; fall; family; farm; farmer; fat; favourite; field; fire; fish; fishing; flash; floor; fly; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; gentleman; ghost; gift; giraffe; girl; glass; glasses; goal; god; gold; golf; grass; green; grey; ground; group; guitar; gun; gymnastics; hair; haircut; hand; hat; head; headache; heart; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; instructor; island; jacket; jail; joke; joy; june; jungle; kangaroo; kick; king; kitten; lady; lake; land; lawn; leaf; leg; lemon; leopard; library; life; light; lightning; line; lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; miss; monday; money; monkey; monster; morning; mother; motor; mouse; mouth; movie; mrs; mud; mum; mushroom; music; musical; name; neck; need; night; noise; november; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; person; pet; piece; pig; pink; pirate; pizza; plan; planet; playground; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rat; red; rescue; rest; restaurant; river; road; robot; rocket; roof; room; rope; round; run; running; salad; sand; sandwich; saturday; school; science; sea; seat; second; september; set; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; shower; side; silver; singing; siren; skeleton; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; stadium; stairs; stand; star; step; storm; story; strawberry; street; summer; sun; sunday; tail; tank; tea; teacher; teaching; team; tent; thought; thursday; tiger; time; toast; today; toilet; tooth; toothbrush; top; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turkey; turn; turning; tv; uncle; walk; walking; wall; war; waste; watch; water; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (749 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; argument; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; barn; basketball; bat; bathroom; battle; bay; beach; bear; beard; bed; bedroom; bee; beer; bench; bird; birthday; biscuit; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boot; border; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; bug; building;

bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; calf; camel; camera; camp; camping; can; cancer; candle; car; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; cemetery; chain; chair; challenge; chat; chef; chess; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; cleaner; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; college; colour; community; competition; computer; container; contest; continent; cook; cookie; cooking; cooperation; coral; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; cup; cupboard; customer; cutlery; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dice; diesel; dimension; dinner; dinosaur; direction; directions; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; drought; duck; dud; eagle; earth; elephant; enemy; engine; episode; evening; event; evil; exercise; eye; face; factory; fair; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fireplace; fish; fishing; flame; flash; flight; flood; floor; flour; fluid; fly; food; foot; football; force; forest; form; fox; frame; freezer; friend; frog; frost; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gate; gear; gentleman; ghost gift; giraffe; girl; girlfriend; glass; glasses; glue; goal; god; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; ham; hat; hate; head; headache; heart; heat; hero; hill; hip; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; insect; instructor; interaction; island; jacket; jail; jam; jewellery; joke; joy; judge; jupe; juice; jungle; junk; kangaroo; kettle; kick; killing; kilometre; king; kiss; kitchen; kite; kitten; knife; lab; laboratory; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leaf; leak; leg; lemon; lemonade; length; leopard; lesson; level; library; lie; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; machinery; magic; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; mechanic; medal; medicine; member; menu; mercy; mess; message; metal; metre; microphone; midnight; milk; mind; miracle; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; motor; mouse; mouth; Mrs; mud; mug; mum; museum; mushroom; music; musical; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; november; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parade; paragraph; parcel; parent; park; parrot; partner; party; pasta; patch; paw; peace; pen; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; plot; point; pole; police; pond; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; roundabout; rubber; run; running; sack; salad; salt; sand; sandwich; Saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; solution; son; song; sound; soup; south; space; speed; spelling; spider; spinach; spirit; spoon; spy; square; stable; stadium; stage; staircase; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; Sunday; survival; sweets; symbol; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; temper; tent; thermometer; thought; thunderstorm; Thursday; tiger; timber; time; tin; toast; today; toe; toilet; tongue; tooth; toothbrush; top; torch; touch; towel; tower; town; toy; track; tractor; train; training; tram; treasure; tree; triangle; trophy; trouble; truck; truth; try; Tuesday; tunnel; turkey; turn; turning; tv; uncle; uniform; unit; university; walk; walking; wall; valley; war; wardrobe; warrior; wasp; waste; watch; water; waterfall; wave; way; website; wedding; Wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yacht; yard; year; yellow; zebra; zone; zoo;

Nouns belonging to school level Year 3 (642 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; animal; ant; apple; arm; army; art; august; baby; back; bacon; bag; ball; balloon; banana; barbecue; bark; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; bee; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boy; boyfriend; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; camel; camera; camp; camping; can; cancer; car; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; chain; chair; challenge; chat; chef; chess; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; club; code; coffee; cold; college; colour; competition; computer; cook; cookie; cooking; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; cup; cupboard; customer; cutlery; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dice; dinner; dinosaur; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fish; fishing; flash; flight; floor; fly; food; foot; football; force; forest; form; fox; frame; freezer; friend; frog; frost; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gate; gear; ghost; gift; girl; glass; glasses; glue; goal; god; gold; golf; grass; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; heart; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; island; jacket; jail; jam; jewellery; joke; joy; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; lab; laboratory; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leg; legend; lemon; lemonade; leopard; lesson; level; library; lie; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; magic; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; medal; medicine; member; menu; mess; message; metal; microphone; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; mouse; mouth; Mrs; mud; mug; mum; museum; music; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pond; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; sack; salad; salt; sand; sandwich; Saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spirit; spoon; square; stadium; stage; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; Sunday; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; temper; tent; thought; thunderstorm; Thursday; tiger; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; train; training; tram; treasure; tree; triangle; trophy; trouble; truck; truth; try; Tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; walk; walking; wall; valley; war; wardrobe; warrior; watch; water; waterfall; wave; way; website; wedding; Wednesday; weed; week; weekend; veil; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 4 (612 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; bark; barn; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; bee; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; butterfly; cake; camera; camp; camping; can; cancer; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; chain; chair; challenge; chat; chef; chess; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; college; colour; competition; computer; container; contest; cook; cookie; cooking; cost; cottage; cough; country; court; cousin; cow; craft; crash; cream; creature; crew; cricket; crime; cross; crystal; cup; cupboard; dance; dancing; daughter; day; death; deck; deer; desert; desk; dessert; devil; diamond; diary; dinner; dinosaur; disco; distance; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fair; fall; family; farm; fat; feeling; fence; ferry; field; fire; fish; fishing; flash; flight; floor; fly; food; foot; football; force; forest; form; fox; frame; freezer; friend; frog; frost; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gate; gear; ghost; gift; girl; girlfriend; glass; glasses; glue; goal; gold; golf; grass; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; ham; hat; hate; head; heart; hero; hill; hip; history; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; island; jacket; jail; jam; jewellery; joke; joy; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leaf; leak; leg; legend; lemon; lemonade; leopard; lesson; level; library; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; mechanic; medal; medicine; mess; message; metal; metre; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; motor; mouse; mouth; Mrs; mud; mug; mum; museum; music; musical; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pony; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; ruler; run; running; sack; salad; sand; sandwich; Saturday; sausage; scarf; school; science; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spoon; square; stable; stadium; stage; staircase; stairs; stand; star; step; stomach; storey; storm; story; strawberry; street; string; student; summer; sun; Sunday; sweets; tail; talk; tank; tea; teacher; teaching; team; teenager; temper; tent; thought; Thursday; tiger; timber; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; train; training; tram; treasure; tree; triangle; trophy; trouble; truck; truth; try; Tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; walk; walking; wall; valley; war; wardrobe; warrior; watch; water; waterfall; wave; way; website; wedding; Wednesday; weed; week; weekend; veil; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yard; year; yellow; zone; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 3 (i.e. vocabulary of school level Year 3)

Alltogether 1051 nouns with the following subdivision.

Nouns belonging to school level Preparatory (459 nouns):

aeroplane; afternoon; air; airport; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bride; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; car; case; cash; castle; cat; cave; cereal; chair; champion; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; club; cold; colour; competition; computer; concert; costume; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; crowd; cup; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dust; ear; earth; electricity; elephant; engine; evening; face; factory; family; farm; farmer; fat; favourite; feeling; fence; ferry; finger; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; Friday; friend; frog; game; garden; gas; gear; ghost; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; heart; heaven; helicopter; helmet; hero; hill; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; ink; island; jacket; jail; jam; jeans; juice; June; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; magazine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; Mrs; mud; mug; mum; museum; music; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; pancake; paper; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pineapple; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince; princess; prize; professor; pub; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; running; safety; salad; sand; sandwich; Saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skeleton; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; Sunday; sweet; sword; system; tail; tea; teacher; team; television; tennis; tent; theatre; thought; thunder; Thursday; tiger; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; traffic; trail; train; training; travel; treasure; tree; trip; trophy; truck; Tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding;

wednesday; week; weekend; vest; whale; wheel; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (520 nouns):

adult; adventure; aeroplane; afternoon; animal; answer; apple; arm; army; arrest; art; baby; bacon; bag; ball; ballet; balloon; bank; barbecue; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; bee; beef; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; brand; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; button; cabin; cake; camel; camping; can; car; carpet; cash; castle; cat; cave; cereal; chain; chair; change; cheese; chess; chest; chicken; chick; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; club; coffee; coin; cold; collar; collection; colour; competition; complex; computer; concert; cook; cookie; cooking; cost; cottage; cotton; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dad; dance; dancer; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; dirt; disco; dive; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; engine; eye; face; fact; factory; fall; family; farm; father; favourite; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; gift; girl; glass; glasses; goal; god; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; hall; hammer; hand; hat; head; heart; heaven; helicopter; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; january; jar; joke; joy; june; jungle; kangaroo; kick; kid; king; kiss; kit; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; lip; living; lounge; love; lunch; luncheon; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mother; mountain; mouse; mouth; mrs; mud; mum; murder; music; name; neck; need; nest; night; noise; note; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; pastry; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; pub; puppy; purple; rabbit; rain; rainbow; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; salad; sandwich; saturday; sauce; school; science; sea; season; seat; second; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; top; towel; town; toy; track; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; white; wife; village; window; wing; winter; witch; wolf; woman; wood; word; world; writing; yard; year; yellow; zebra;

Nouns belonging to school level Year 2 (642 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; animal; ant; apple; arm; army; art; august; baby; back; bacon; bag; ball; balloon; banana; barbecue; bark; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; bee; beef; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boy; boyfriend; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; camel; camera; camp; camping; can; cancer; car; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; chain; chair; challenge; chat; chef; chess; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; club; code; coffee; cold; college; colour; competition; computer; cook; cooking; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; cup; cupboard; customer; cutlery; dance; dancing; daughter; day; death; december; desk; deer; desert; desk; dessert; devil; diamond; diary; dice; dinner; dinosaur; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fish; fishing; flash; flight; floor; flour; fly; food; foot; football; force; forest; form; fox; frame; friday; friend; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gate; gear; ghost; gift; girl; glass; glasses; glue; goal; god; gold; golf; grass; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; heart; heat; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; island; jacket; jail; jam; jewellery; joke; joy; june; jungle; junk; kangaroo; kettle; kit; killing; king; kiss; kitchen; knife; kitten; king; lab; laboratory; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leg; legend; lemon; lemonade; leopard; lesson; level; library; lie; life; light; lightning; line; lion; living; log; lounge; love; lunch; luncheon; machine; magic; mail; man; mango; mark; market; mask; master; may; meal; medal; medicine; member; menu; mess; message; metal; microphone; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; month; morning; mother; mouse; mouth; mrs; mud; mug; mum; museum; music; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pond; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; salad; salt; sand; sandwich; saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skateboard; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; space; speed; spelling; spider; spirit; spoon; square; stadium; stage; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; sunday; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; tent; thought; thunderstorm; thursday; tiger; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; towel; tower; town; toy; track; train; training; treasure; tree; trophy; trouble; truck; truth; try; tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; walk; walking; wall; valley; war; wardrobe; warrior; watch; water; waterfall; wave; way; website; wedding; wednesday; week; weekend; veil; whale; wheel; white; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; word; world; worry; wrist; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 3 (1051 nouns):

account; accuracy; ache; act; action; actor; ad; addition; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; album; alcohol; allowance; alphabet; angel; angle; animal; ankle; answer; ant; apartment; apple; area; arm; army; arrest; art; artist; attention; audience; august; aunt; author; autumn; award; baby; back; backpack; bacon; bag; bakery; balcony; ball; ballet; balloon; banana; bandage; bank; barbecue; barber; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bean; bear; beauty; bed; bedroom; bee; beef; beer; behaviour; bench; berry; bicycle; bike; bin; bird; birthday; bit; bite; black; blackboard; blade; blanket; blood; blue; boat; body; bomb; bone; book; booking; bottle; bowl; box; boxing; boy; boyfriend; brain; brake; branch; brand; bread; breakfast; breath; breed; brick; bridle; bridge; brother; brown; brush; bucket; building; bulb; bull; bullet; bunch; bus; business; butter; butterfly; button; cabbage; cabin; cake; calculator; calendar; camel; camera; camp; camping; campsite; can; cancer; cap; car; carnival; carpet; carrot; cartoon; case; cash; casserole; cast; castle; cat; cause; cave; ceiling; cereal; chain; chair; challenge; champion; championship; chance; change; chat; check; cheese; chef; chess; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; clutch; coal; coat; coconut; code; coffee; coin; cola; cold; collar; collection; college; colour; column; comedy; comic; company; competition; complex; concert; cook; cookie; cooking; core; corn; cost; costume; cottage; cotton; cough; count; counter; country; courage; court; cousin; cow; crab; crack; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crowd; crystal; cup; cupboard; curve; customer; cutlery; dad; dance; dancer; dancing; darkness; daughter; dawn; day; death; december; deck; deer; desert; design; desire; desk; dessert; detective; dice; diamond; diary; dice; dinner; dinosaur; dirt; disaster; dish; disco; disease; disguise; dishwasher; disk; distance; dive; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; drum; dust; duty; ear; earth; earthquake; east; edge; electricity; element; elephant; email; empire; enemy; energy; engine; enthusiasm; entrance; envelope; error; evening; evil; excitement; exercise; experiment; expert; explosion; explosive; eye; face; fact; factory; fall; family; fantasy; farm; farmer; fashion; fat; father; favourite; fear; feeling; female; fence; ferry; field; fight; figure; finger; fire; fish; fishing; fist; flash; flat; flesh; flight; floor; flour; flower; fly; fog; food; foot; football; force; forest; form; fortune; fox; frame; friday; friend; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gas; gate; gear; ghost; gift; girl; glass; glasses; glue; goal; goalkeeper; god; gold; golf; government; grandmother; grandson; grass; green; grey; grin; groom; ground; group; guard; guitar; gun; gym; gymnastics; hail; hair; hairdresser; hall; ham; hammer; hand; happiness; harmony; hat; hate; head; health; heart; heat; heaven; hedge; height; helicopter; hell; helmet; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honesty; honey; hope; horn; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; information; ink; invasion; invention; investigation; iron; island; jacket; jail; jam; january; jar; jaw; jeans; jewellery; joke; journal; journey; joy; juice; july; june; jungle; junk; kangaroo; keeper; kettle; kick; kid; killing; king; kiss; kit; kitchen; knife; kitten; knot; lab; laboratory; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; lane; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; liar; library; lie; life; light; lightning; lightning; line; link; lion; lip; literacy; litre; liver; living; log; lounge; love; luck; luggage; lunch; luncheon; machine; magazine; magic; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; mayor; meal; meat; medal; medication; medicine; meeting; member; membership; menu; mess; message; metal; microphone; midnight; milk; mind; miner; minute; mirror; miss; missile; mist; mix; mixture; mode; model; monday; money; monkey; monster; month; moonlight; morning; mother; mountain; mouse; mouth; mr; mrs; mud; mug; mum; murder; muscle; museum; music; mystery; name; nap; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; note; notice; number; nurse; oak; object; obstacle; ocean; october; office; officer; oil; onion; opening; opera; oven; owl; owner; oxygen; pace; pack; pain; paint; painting; pair; palace; pan; pancake; parent; park; parking; partner; party; password; pastry; patch; pattern; pea; peace; peach; pen; pencil; penguin; people; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pineapple; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; pocket; poem; point; pole; police; pond; pony; pork; port; post; poster; potato; prawn; present; president; priest; prince; princess; prison; prisoner; prize; problem; professional; professor; promise; property; pub; pudding; puppy; purple; push; pyramid; quest; question; quiet; quiz; rabbit; radio; rain; rainbow; raincoat; rat; razor; reason; recipe; rectangle; red; reflection; region; relief; reply; report; rescue; research; rest; restaurant; revenge; rice; right; river; road; robbery; robot; rock; rocket; roof; room; rope; rose; round; rubber; rule; ruler; run; running; runway; saddle; safety; sailing; salad; salmon; salt; sand; sandwich; saturday; sauce; sausage; scar; scarf; school; science; scientist; scrap; scratch; sea; season; seat; second; secret; security; seed; self; sense; series; set; setting; shadow; shape; shark; shed; sheep; sheet; shield; ship; shirt; shoe; shooting; shop; shopping; shorts; shot; shoulder; show; shower; side; sign; silence; silver; singer; singing; sink; sir; siren; sister; site; site; skate; skateboard; skeleton; skiing; skull; skin; slip; sleep; smile; smoke; smoking; snack; snake; snow; soap; soil; soldier; son; song; sound; soup; source; south; space; species; speech; speed; spelling; sphere; spider; spirit; spoon; sport; squad; square; stadium; stage; stairs; stand; star; state; statue; steak; steam; step; stick; stomach; stone; storey; storm; story; straw; strawberry; stream; street; stretch; strike; stroke; student; studio; study; substance; sugar; summer; sun; sunday; sunglasses; sunlight; supermarket; supporter; surface; surfing; surroundings; swan; sweat; sweet; switch; sword; system; tail; talk; tank; taste; tea; teacher; teaching; team; teaspoon; teenager; telescope; television; tennis; tent; test; text; theatre; thought; thunder; thunderstorm; thursday; tick; tiger; time; tin; title; toast; today; toe; toilet; tomato; tomb; tongue; tooth; top; torch; tornado; touch; tournament; towel; tower; town; toy; track; traffic; train; training; transport; travel; tray; treasure; tree; tribe; trip; troops; trophy; trouble; truck; trumpet; truth; try; tube; tuesday; tunnel; turn; turning; tv; twin; type; uncle; underwear; uniform; unit; walk; walking; wall; wallet; valley; van; war; wardrobe; warehouse; warrior; watch; water; waterfall; wave; way; weapon; weather; website; wedding; wednesday; week; weekend; vegetable; weight; veil; vest; white; wheat; wheel; white; vice; video; wife; village; wind; window; wing; winter; witch; wolf; wine; wine; wing; winner; winter; violin; wire; witch; volcano; wolf; woman; wood; word; world; wom; worry; vote; wrist; writer; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 4 (825 nouns):

act; action; actor; ad; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; angel; animal; ankle; answer; ant; apartment; apple; area; arm; army; art; attention; august; aunt; award; baby; back; backpack; bacon; bag; balcony; ball; ballet; balloon; banana; bandage; bank; barbecue; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bear; beauty; bed; bedroom; beef; beer; behaviour; bench; bicycle; bike; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boxing; boy; boyfriend; brain; branch; bread; breakfast; breath; breed; brick; bridge; brother; brown; brush; bucket; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; ceiling; cereal; chain; chair; challenge; champion; championship; chance;

chat; cheese; chef; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; coat; code; coffee; cold; collar; colour; comedy; comic; competition; computer; concert; cook; cookie; cooking; cost; costume; cottage; cough; country; courage; court; cousin; cow; crack; craft; crash; cream; creature; crew; cricket; crime; cross; crowd; crystal; cup; cupboard; dad; dance; dancer; dancing; darkness; daughter; day; death; deck; deer; desert; dessert; detective; devil; diamond; diary; dinner; dinosaur; dirt; disaster; disco; distance; dog; doll; door; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; electricity; element; elephant; enemy; energy; engine; entrance; envelope; evening; evil; excitement; exercise; experiment; explosion; explosive; eye; face; fact; factory; fall; family; farm; fashion; fat; father; fear; feeling; fence; field; fight; figure; fire; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forest; form; fox; frame; friday; friend; freight; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gas; gate; gear; ghost; girl; glasses; goal; gold; golf; government; grandson; grandson; grass; green; grey; grin; ground; group; guard; guitar; gun; gym; gymnastics; hair; hair; hall; ham; hand; hammer; hand; happiness; hat; hate; head; health; heart; heat; heaven; height; helicopter; hell; helmet; hero; hill; history; hole; holiday; home; homework; honey; hope; horn; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; information; invasion; invention; island; jacket; jail; jam; jar; jeans; jewellery; journey; joy; juice; july; june; jungle; junk; kangaroo; kettle; kick; kid; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; library; life; light; lighting; lightning; line; lion; literacy; living; log; lounge; love; luck; luggage; lunch; lunchtime; machine; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; meal; meat; medal; medicine; meeting; mess; message; metal; midnight; milk; mind; minute; mirror; miss; mist; mix; mixture; model; monday; money; monkey; monster; month; morning; mother; mouse; mouth; mrs; mud; mum; murder; muscle; museum; music; mystery; name; nap; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; note; notice; number; object; obstacle; ocean; october; office; oil; onion; opening; oven; owner; pack; pain; paint; pair; palace; paper; parachute; parcel; parent; park; party; patch; pattern; peace; peach; pencil; penguin; people; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pizza; place; plane; planet; planning; plant; plastic; playground; pleasure; pocket; point; pole; police; pony; post; poster; present; president; prince; princess; prison; prize; problem; professional; professor; property; puppy; purple; push; quest; question; quiet; quiz; rabbit; radio; rain; rainbow; raincoat; rat; reason; recipe; rectangle; red; reply; rescue; rest; restaurant; revenge; rice; right; river; road; robbery; robot; rock; rocket; roof; room; rope; rose; round; rubber; rule; ruler; run; running; saddle; safety; salad; sand; sandwich; saturday; sauce; sausage; scar; scarf; school; science; scientist; sea; season; seat; second; secret; security; seed; self; sense; series; set; setting; shadow; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shorts; shot; shoulder; show; shower; side; sign; silence; silver; singer; singing; sink; sir; siren; size; skate; skateboard; skeleton; skiing; skill; skin; skull; sky; slap; sleep; smoke; snack; snow; soldier; son; song; sound; soup; space; spaces; speed; spelling; sphere; spider; spoon; sport; squad; square; stadium; stage; stairs; stand; star; state; statue; step; stick; stomach; stone; storey; storm; story; strawberry; stream; street; stretch; strike; string; stroke; study; sugar; summer; sun; sunday; sunlight; supermarket; surface; surfing; surroundings; sweat; sweet; switch; sword; system; tail; talk; tank; taste; tea; teacher; teaching; team; teenager; telescope; television; tennis; tent; test; thought; thunder; thursday; tick; tiger; time; tin; toast; today; toe; toilet; tomato; tongue; tooth; top; torch; tornado; touch; tournament; towel; tower; town; toy; track; traffic; trail; train; training; transport; travel; treasure; tree; trip; trophy; trouble; truck; try; tube; tuesday; tunnel; turn; turning; tv; twin; type; uncle; walk; walking; wall; valley; van; war; wardrobe; warrior; watch; water; waterfall; wave; way; weapon; weather; wedding; wednesday; week; weekend; vegetable; weight; whale; wheat; wheel; white; video; wife; village; wind; window; vine; wing; winner; winter; witch; volcano; wolf; woman; wood; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 4 (i.e. vocabulary of school level Year 4)

Altogether 1072 nouns with the following subdivision.

Nouns belonging to school level Preparatory (459 nouns):

accident; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bridge; brother; brush; bus; butterfly; cake; camera; camping; can; car; case; cash; castle; cat; cave; cereal; chair; champion; cheese; cherry; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crash; crew; cricket; cross; crowd; dance; dancing; day; desert; dessert; devil; diary; dinner; dinosaur; disco; dog; doll; door; dream; dress; drink; drive; duck; ear; earth; electricity; elephant; engine; evening; face; factory; fair; family; farm; fat; feeling; fence; field; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gas; gear; ghost; girl; glove; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; heart; heaven; helicopter; helmet; hero; hill; hip; history; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; jam; jar; jeans; june; july; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; mat; match; meal; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; mrs; mud; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; paper; parade; parent; park; party; pasta; patch; peace; pear; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; plant; playground; poison; pole; police; pony; present; prince; princess; prize; professor; project; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; running; sack; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; ship; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; temple; tennis; tent; thought; thunder; thursday; tiger; timber; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; triangle; trip; trophy; truck; tuesday; turn; turning; tv; type; umbrella; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; video; village; wind; window; winner; winter; witch; woman; wood; word; worm; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 1 (512 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; art; baby; bacon; bag; ball; ballet; balloon; barn; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; beef; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; butter; butterfly; button; cabin; cake; camping; can; car; carpet; cash; castle; cat; cave; century; cereal; chain; chair; cheese; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; cloud; club; coffee; cold; collar; colour; competition; computer; concert; contest; cook; cookie; cooking; cost; cottage; court; cousin; cow; crash; cream; creature; cricket; crime; cross; cup; cupboard; dad; dance; dancer; dancing; day; desert; designer; devil; diamond; dinner; dinosaur; dirt; disco; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; emergency; engine; eye; face; fact; factory; fall; family; farm; fashion; fat; father; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; freezer; friday; friend; frog; fruit; fun; fur; game; garden; gardening; gate; gear; ghost; girl; glass; glasses; goal; goat; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; haircut; hall; hammer; hand; hat; head; heart; heaven; helicopter; help; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; jam; jar; joy; june; jungle; kangaroo; kick; kid; killer; king; kiss; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; leaf; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mosquito; mother; motor; mountain; mouse; mouth; mrs; mud; mum; murder; murderer; music; musical; name; nature; neck; need; nest; night; noise; note; number; ocean; opening; oven; paint; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; performance; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; poison; pole; police; pony; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rainforest; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; sail; salad; sand; sandwich; saturday; sauce; school; science; sea; season; seat; second; september; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; suitcase; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; top; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; village; wind; window; wing; winter; witch; wolf; volleyball; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (612 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; bark; barn; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boot; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; butter; butterfly; cake; camera; camp; camping; can; cancer; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; chain; chair; challenge; chat; chef; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; colour; competition; computer; container; contest; cook; cookie; cooking; cost; cottage; cough; country; court; cousin; cow; craft; crash; cream; creature; crew; cricket; crime; cross; crystal; cup; cupboard; dance; dancing; daughter; day; death; deck; deer; desert; dessert; devil; diamond; diary; dinner; dinosaur; disco; distance; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fair; fall; family; farm; fat; feeling; fence; field; fire; fish; fishing; flash; flight; floor; fly; food; foot; football; force; forest; form; fox; frame; freezer; friday; friend; frog; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gate; gear; ghost; girl; girlfriend; glass; glasses; goal; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; hate; heart; heat; hero; hill; hip; history; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; island; jacket; jail; jam; jewellery; joy; judge; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leaf; leak; leg; legend; lemon; lemonade; leopard; lesson; level; library; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; mail; man; mango; march; mark; master; match; matter; may; meal; meat; mechanic; medal; medicine; mess; message; metal; metre; midnight; milk; mind; mirror; miss; monday; money; monster; month; morning; mother; motor; mouse; mouth; mrs; mud; mum; museum; music; musical; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; oven; pain; paint; pair; palace; paper; parade; parcel; parent; park; parrot; party; pasta; patch; peace; pen; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pony; present; president; prince; princess; prize; problem; professor; puppy; purple; push; rabbit; radio; rain; rainbow; rat; red; rescue; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; sack; salad; sand; sandwich; saturday; sausage; scarf; school; science; sea; seat; second; secret; seed; september; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singer; sink; siren; skate; skeleton; skin; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spoon; square; stable; stadium; stage; staircase; stairs; stand; star; step; stomach; storey; storm; story; strawberry; street; string; summer; sun; sunday; sweets; tail; talk; tank; tea; teacher; teaching; team; teenager; temper; tent; thought; thursday; tiger; timber; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; tractor; train; training; treasure; tree; triangle; trophy; trouble; truck; try; tuesday; tunnel; turn; turning; tv; uncle; university; walk; walking; wall; valley; war; wardrobe; warrior; waste; watch; water; waterfall; wave; way; wedding; wednesday; weed; week; weekend; west; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; writing; yard; year; yellow; zone; zoo;

Nouns belonging to school level Year 3 (825 nouns):

act; action; actor; ad; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; angel; animal; ankle; answer; ant; apartment; apple; area; arm; army; art; attention;

august; aunt; award; baby; back; backpack; bacon; bag; balcony; ball; ballet; balloon; banana; bandage; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bear; beauty; bed; bedroom; beef; beer; behaviour; bench; bicycle; bike; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boxing; boy; boyfriend; brain; branch; bread; breakfast; breath; breed; brick; bridge; brother; brown; brush; bucket; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; ceiling; cereal; chain; chair; challenge; champion; championship; chance; chat; cheese; chef; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; coat; code; coffee; cold; collar; colour; comedy; comic; competition; computer; concert; cook; cookie; cooking; cost; costume; cottage; country; courage; court; cousin; cow; crack; craft; crash; cream; creature; crew; cricket; crime; crisis; cross; crowd; crystal; cup; cupboard; cure; customs; dad; damage; dance; dancer; dancing; danger; darkness; daughter; day; death; deck; deer; desert; dessert; detective; devil; diamond; diary; dinner; dinosaur; dirt; disaster; disco; disguise; distance; dog; doll; door; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; electricity; element; elephant; enemy; energy; engine; entrance; envelope; evening; evil; excitement; exercise; experiment; explosion; explosive; eye; face; fact; factory; fall; family; farm; fashion; fat; father; fear; feeling; fence; field; fight; figure; fire; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forest; form; fox; frame; friday; friend; fright; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gas; gate; gear; ghost; girl; glass; glasses; goal; gold; golf; government; grandmother; grandson; grass; green; grey; grin; ground; group; guard; guide; guitar; gun; gym; gymnastics; hail; hair; hall; ham; hammer; hand; happiness; hat; hate; head; health; heart; heat; heaven; height; helicopter; hell; helmet; hero; hill; history; hole; holiday; home; homework; honey; hope; horn; horse; hospital; hostel; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; information; invasion; invention; island; jacket; jail; jam; jar; jazz; jeans; jewellery; journey; joy; judge; juice; july; june; jungle; junk; kangaroo; kettle; kick; kid; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; lead; leader; leaf; leak; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; library; life; light; lighting; lightning; line; lion; liquid; literacy; litter; living; loaf; log; lottery; lounge; love; luck; luggage; lunch; lunchtime; machine; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; meal; meat; medal; medicine; meeting; mess; message; metal; metre; midnight; milk; mind; minute; mirror; misery; miss; mist; mix; mixture; model; monday; money; monkey; monster; month; morning; mosquito; motor; mountain; mouse; mouth; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; ocean; october; office; oil; onion; opening; oven; owner; pack; pain; paint; pair; pants; paper; parachute; parade; paradise; parcel; parent; park; parrot; party; passage; passenger; passport; pasta; patch; patience; pattern; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; performance; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; plumber; pocket; point; poison; pole; police; pony; post; poster; predator; pressure; president; pressure; price; prince; princess; prison; prize; problem; professional; professor; project; property; protection; pulse; pump; punishment; puppy; purple; purse; push; puzzle; quest; question; quiet; quiz; rabbit; radio; railway; rain; rainbow; raincoat; rainforest; rat; realm; reason; recipe; rectangle; red; referee; remains; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; right; risk; river; road; robbery; robot; rock; rocket; roof; room; root; rope; rose; round; rubber; rule; ruler; rumour; run; running; sack; saddle; sadness; safety; sail; salad; sand; sandwich; saturday; sauce; saucer; sausage; saving; scar; scarf; school; science; scientist; scissors; screen; sea; season; seat; second; secret; security; seed; self; sense; september; series; servant; set; setting; shade; shadow; shame; shampoo; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; side; sign; silence; silver; simulation; singer; singing; sink; sir; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smile; smoke; snack; snake; snow; society; soldier; son; song; soul; sound; soup; south; souvenir; space; spade; species; speed; spelling; sphere; spider; spoon; sport; squad; square; stable; stadium; stage; staircase; stairs; stand; star; starvation; state; statue; status; steel; step; stick; stomach; stone; storey; storm; story; strawberry; stream; street; strength; stretch; strike; string; stroke; study; style; success; sugar; suitcase; summer; summit; sun; sunday; sunlight; sunset; sunshine; supermarket; surface; surfing; surgery; surroundings; sweat; sweet; sweets; switch; sword; system; tail; talk; talks; tank; taste; tea; teacher; teaching; team; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; test; theft; thief; thought; throat; throne; thunder; thursday; tick; tide; tiger; tights; timber; time; tin; toast; today; toe; toilet; tomato; ton; tone; tongue; tooth; top; torch; tornado; torture; touch; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; training; transport; travel; treasure; tree; triangle; trip; trophy; trouble; truck; try; tube; tuesday; tunnel; turn; turning; tv; twin; type; umbrella; uncle; university; waist; walk; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warrior; waste; watch; water; waterfall; wave; way; weapon; weather; webcam; wedding; wednesday; weed; week; weekend; vegetable; vegetarian; weight; velvet; west; whale; wheel; whistle; white; video; widow; wife; village; wind; window; wine; wing; winner; winter; violence; wish; witch; volcano; wolf; volleyball; woman; wood; wool; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zone; zoo;

Nouns belonging to school level Year 4 (1072 nouns):

accident; acid; act; action; actor; ad; adult; adventure; advertisement; aeroplane; afternoon; age; agent; air; airport; alarm; ambulance; amusement; analysis; angel; anger; animal; ankle; answer; ant; apartment; apple; april; arch; area; am; army; art; attention; august; aunt; award; baby; back; backpack; bacon; badge; bag; balcony; ball; ballet; balloon; banana; bandage; bark; barn; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bear; beauty; bed; bedroom; beef; beer; behaviour; bench; bicycle; bike; bikini; bill; bird; birth; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boost; boot; bottle; bow; bowl; box; boxing; boy; boyfriend; bracelet; brain; branch; bread; breakfast; breath; breed; breeze; brick; bridge; brother; brown; brush; bucket; budget; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; career; carpet; case; cash; castle; cat; cattle; cave; ceiling; cereal; celebration; cent; centimetre; century; cereal; ceremony; chain; chair; challenge; champion; championship; chance; channel; chat; cheek; cheese; chef; cherry; chest; chicken; child; chill; chimney; chin; chip; chocolate; choice; choir; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; clown; club; coast; coat; code; coffee; cold; coldness; collar; colour; comedy; comfort; comic; competition; computer; concert; concrete; confidence; container; contest; conversation; cook; cookie; cooking; copper; cost; costume; cottage; cough; country; courage; court; cousin; cow; crack; craft; crash; cream; creature; crew; cricket; crime; crisis; cross; crowd; crystal; cup; cupboard; cure; customs; dad; damage; dance; dancer; dancing; danger; darkness; dash; daughter; day; death; deck; deer; description; desert; designer; dessert; detective; devil; diamond; diary; dictionary; dinner; dinosaur; dirt; disaster; discipline; disco; disguise; distance; distraction; dog; doll; dollar; door; doorway; drama; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; elbow; election; electricity; element; elephant; emergency; enemy; energy; engine; entertainment; entrance; envelope; estate; evening; evil; exam; examination; excitement; exercise; experience; experiment; exploration; explosion; explosive; eye; face; fact; factory; fair; fall; family; farm; fashion; fat; father; fear; freedom; feeling; fence; festival; fever; field; fight; figure; fire; firm; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forehead; forest; form; fountain; fox; frame; freezer; friday; friend; frog; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gas; gate; gear; gender; ghost; girl; girlfriend; glass; glasses; glove; goal; goat; gold; golf; government; grandfather; grandmother; grandson; grasp; grass; grave; green; grey; grin; ground; group; guard; guide; guitar; gun; gym; gymnastics; hail; hair; haircut; hall; ham; hammer; hand; handbag; happiness; harm; hat; hate; head; heading; headquarters; health; heart; heat; heater; heaven; heel; height; helicopter; hell; helmet; help; hero; hill; hip; history; hole; hole; holiday; home; homework; honey; hope; horn; horse; hospital; hostel; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; independence; information; injury; insight; interview; invasion; invention; island; jacket; jail; jam; jar; jazz; jeans; jewel; jewellery; journey; joy; judge; juice; july; june; jungle; junk; kangaroo; kettle; kick; kid; killer; killing; king; kingdom; kiss; kitchen; kite; kitten; knee; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; lead; leader; leaf; leak; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; liberty; library; life; light; lighting; lightning; line; lion; liquid; literacy; litter; living; loaf; log; lottery; lounge; love; luck; luggage; lunch; lunchtime; lyrics; machine; mail; male; man; mango; mansion; manual; map; march; mark; market; mask; master; mat; match; material; matter; may; meal; meat; mechanic; medal; medicine; meeting; mess; message; metal; metre; midnight; milk; mind; minute; mirror; misery; miss; mist; mix; mixture; model; monday; money; monkey; monopoly; monster; month; morning; mosquito; mother; motor; mountain; mouse; mouth; mrs; mud; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; neighbourhood; nephew; nerve; nest; news; newspaper; nickname; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; ocean; october; office; official; oil; onion; opening; opposite; orphan; oven; owner; pack; pain; paint; pair; palace; pants; paper; parachute; parade; paradise; parcel; parent; park; parrot; party; passage; passenger; passport; pasta; patch; patience; pattern; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; performance; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; plumber; pocket; point; poison; pole; police; pony; post; poster; predator; present; president; pressure; price; prince; princess; prison; prize; problem; professional; professor; project; property; protection; pulse; pump; punishment; puppy; purple; purse; push; puzzle; quest; question; quiet; quiz; rabbit; radio; railway; rain; rainbow; raincoat; rainforest; rat; realm; reason; recipe; rectangle; red; referee; remains; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; right; risk; river; road; robbery; robot; rock; rocket; roof; room; root; rope; rose; round; rubber; rule; ruler; rumour; run; running; sack; saddle; sadness; safety; sail; salad; sand; sandwich; saturday; sauce; saucer; sausage; saving; scar; scarf; school; science; scientist; scissors; screen; sea; season; seat; second; secret; security; seed; self; sense; september; series; servant; set; setting; shade; shadow; shame; shampoo; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; side; sign; silence; silver; simulation; singer; singing; sink; sir; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smile; smoke; snack; snake; snow; society; soldier; son; song; soul; sound; soup; south; souvenir; space; spade; species; speed; spelling; sphere; spider; spoon; sport; squad; square; stable; stadium; stage; staircase; stairs; stand; star; starvation; state; statue; status; steel; step; stick; stomach; stone; storey; storm; story; strawberry; stream; street; strength; stretch; strike; string; stroke; study; style; success; sugar; suitcase; summer; summit; sun; sunday; sunlight; sunset; sunshine; supermarket; surface; surfing; surgery; surroundings; sweat; sweet; sweets; switch; sword; system; tail; talk; talks; tank; taste; tea; teacher; teaching; team; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; test; theft; thief; thought; throat; throne; thunder; thursday; tick; tide; tiger; tights; timber; time; tin; toast; today; toe; toilet; tomato; ton; tone; tongue; tooth; top; torch; tornado; torture; touch; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; training; transport; travel; treasure; tree; triangle; trip; trophy; trouble; truck; try; tube; tuesday; tunnel; turn; turning; tv; twin; type; umbrella; uncle; university; waist; walk; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warrior; waste; watch; water; waterfall; wave; way; weapon; weather; webcam; wedding; wednesday; weed; week; weekend; vegetable; vegetarian; weight; velvet; west; whale; wheel; whistle; white; video; widow; wife; village; wind; window; wine; wing; winner; winter; violence; wish; witch; volcano; wolf; volleyball; woman; wood; wool; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zone; zoo;

Appendixes AF-AM

Reprints of the original publications [P1]–[P8] to be added here.

PART II

The second manuscript version of the doctoral dissertation that was submitted for official evaluation on 19 August 2014

Lauri Lahti
Department of Computer Science and Engineering
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**Computer-Assisted Learning Based on Cumulative
Vocabularies, Conceptual Networks and Wikipedia
Linkage**

(in Finnish: Tietokoneavusteinen oppiminen perustuen
karttuviin sanastoihin, käsiteverkostoihin ja Wikipedian
linkitykseen)

Manuscript version 19 August 2014

Abstract

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Lauri Lahti (full name Lauri Esko Lahti, born 1975)

Name of manuscript:

Computer-Assisted Learning Based on Cumulative Vocabularies, Conceptual Networks and Wikipedia Linkage

Publisher: Aalto University School of Science

Unit: Department of Computer Science and Engineering

Series: (not shown here)

Field of research: Computer science

Abstract

We propose new methods and frameworks for computer-assisted learning. The work relies on nine peer-reviewed conference articles proposing new computational methods based on self designed and implemented software prototypes supplied with empirical user tests with them. We introduce sample high-frequency lists and conceptual relationships generated by students and comparison of rankings. First, we propose supporting different collaborator roles to address personal needs of each learner participating in collaboration and combining text-based parallel individual discussion chains that are illustrated cumulatively in collaboratively agreed concept maps. Next, we propose a new method for guided generation of concept maps from open access online knowledge resources of hyperlink network of the Wikipedia online encyclopedia (<http://www.wikipedia.org>). Then, we propose a new method for generating personalized learning paths from the Wikipedia by following inter-article hyperlink chains based on various rankings that are retrieved from the statistics of the articles. We extend the previous approach to manage simultaneous parallel ranking lists, diversely branching structures and different consecutive temporal versions of Wikipedia articles. Next, we propose a wiki representing pedagogical knowledge with a collaboratively edited collection of concept maps enabling to analyze maturing of knowledge according to various learner-driven criteria and to define pedagogically motivated learning paths and educational games. Then, we propose a new method to support the learner's knowledge adoption based on concept mapping relying on three perspectives of learner's knowledge, learning context and learning objective, each represented by a learning concept network, so that the learner explores ranking-based routings connecting learning concept networks based on the shortest hyperlink chains between corresponding Wikipedia articles. We propose a new framework relying on pedagogic conceptual network generated by linking the most essential concepts of a learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary enabling the learner to adopt vocabulary by traversing links of pedagogic conceptual network in a sequential process having tailored

variation and repetition computed based on theory of spaced learning and supplied with visualizations. We propose a new framework relying on cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic and alternating the distribution of enabled hyperlinks letting the learner to adopt knowledge by exploring hyperlink network and the shortest paths between concepts of vocabulary. We provide some estimates for the properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile database for cumulatively growing vocabularies corresponding to six language ability levels. Besides explaining results of the articles, we define terminology and background of the research, we combine theoretical and empirical analysis related to the research and we make concluding remarks summarizing the results of the research.

Keywords: intelligent tutoring, Wikipedia, knowledge management, ontology, semantic web, concept map, associative network, vocabulary, language acquisition, wiki, learning model, small-world network, scale-free network, spaced learning, knowledge adoption, collaborative learning environment, educational framework

List of publications and the contributions of the author

This manuscript is based on following nine publications [P1]-[P9] that have been published in peer-reviewed conference proceedings in years 2009–2014. In all of these publications Lauri Lahti has been the sole author and he has self designed and implemented software prototypes and carried out empirical user tests with them. Besides explaining results of publications, this manuscript offers introduction defining terminology and background of the research, supplementing theoretical and empirical analysis related to the research and finally concluding remarks summarizing the results of the research. The research of these publications has been carried out by Lauri Lahti at Aalto University School of Science (formerly Helsinki University of Technology until end of year 2009, then Aalto University School of Science and Technology until end of year 2010).

P1: Lahti, L. (2009a). Assistive tool for collaborative learning of conceptual structures. Proc. 13th Human Computer Interaction International 2009, Part III (Universal Access in Human-Computer Interaction – Applications and Services), 19–24 July 2009, San Diego, CA, USA (ed. Stephanidis, C.). LNCS 5616, Springer, 53–62. Print ISBN 978-3-642-02712-3 and Online ISBN 978-3-642-02713-0. http://link.springer.com/chapter/10.1007/978-3-642-02713-0_6

P2: Lahti, L. (2009b). Guided generation of pedagogical concept maps from the Wikipedia. Proc. World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education (E-Learn 2009). 26–30 October 2009, Vancouver, B.C., Canada (eds. Bastiaens, T. et al.). Association for the Advancement of Computing in Education (AACE), Chesapeake, Virginia, USA, 1741–1750. ISBN 1-880094-76-2. <http://www.edlib.org/p/32712>

P3: Lahti, L. (2010a). Personalized learning paths based on Wikipedia article statistics. Proc. 2nd International Conference on Computer Supported Education (CSEDU 2010), 7–10 April 2010, Valencia, Spain (eds. Cordeiro, J. et al.), Vol. 1, 110–120. SciTePress, Institute for Systems and Technologies of Information, Control and Communication (INSTICC). ISBN 978-989-674-023-8. <http://dx.doi.org/10.5220/0002800901100120>

P4: Lahti, L. (2010b). Educational tool based on topology and evolution of hyperlinks in the Wikipedia. Proc. 10th IEEE International Conference on Advanced Learning Technologies (ICALT 2010), 5–7 July 2010, Sousse, Tunisia (eds. Jemni, M. et al.), 233–235. ISBN 978-0-7695-4055-9 and ISBN 978-1-4244-7144-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5571281

P5: Lahti, L. (2011a). ConceptMapWiki – a collaborative framework for agglomerating pedagogical knowledge. Proc. 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), 6–8 July 2010, Athens, Georgia, USA (eds. Aedo, I. et al.), 163–165. Online ISBN 978-0-7695-4346-8 and Print ISBN 978-1-61284-209-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5992312

P6: Lahti, L. (2011b). Educational concept mapping method based on high-frequency words and Wikipedia linkage. Proc. 4th International Conference on Internet Technologies and Applications (ITA11), 6–9 September 2011, Wrexham, North Wales, UK (eds. Grout, V. et al.). Glyndwr University, Wrexham, Wales, UK. ISBN 978-0-946881-68-0. <http://www.ita11.org/papers.html>; <http://www.ita11.org/detailedProgramme.html>; <http://www.lulu.com/shop/vic-grout-and-stuart-cunningham-and-denise-oram-and-rich-picking/proceedings-of-the-fourth-international-conference-on-internet-technologies-and-applications-ita-11/ebook/product-17431522.html>

P7: Lahti, L. (2012). Educational framework for adoption of vocabulary based on Wikipedia linkage and spaced learning. Proc. Global Learn 2012: Global Conference on Learning and Technology, online conference on 6 November 2012 (eds. Bastiaens, T., & Marks, G.), 8–13.

Association for the Advancement of Computing in Education (AACE). ISBN 1-880094-99-1. <http://www.editlib.org/p/42033/>

P8: Lahti, L. (2013). Educational framework based on cumulative vocabularies, conceptual networks and Wikipedia linkage. Proc. London International Conference on Education (LICE 2013). 4–6 November 2013, London, UK (eds. Shoniregun, C., & Akmayeva, G.), 470–478. ISBN 978-1-908320-16-2.

P9: Lahti, L. (2014). Educational exploration based on conceptual networks generated by students and Wikipedia linkage. Proc. World Conference on Educational Multimedia, Hypermedia and Telecommunications 2014 (EdMedia 2014) (eds. Herrington, J. et al.), 964–974. ISBN 978-1-939797-08-7. Association for the Advancement of Computing in Education (AACE), Chesapeake, VA, USA. <http://www.editlib.org/p/147608/>

A short characterization of each of these nine publications is provided in Appendix A and reprints of the original publications are in Appendixes AO–AW.

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Preface

I want to express my warmest thanks to people who have helped me in the process of research that has produced this manuscript – and in fact my thanks to everyone I have been with during my life since I have learned something important unique from all of you.

(not shown here)

I dedicate my work to all generations of learners and educators worldwide.

Place and date

Lauri Lahti

PART I. Providing guidance in a network of educational knowledge

Chapter 1. Introduction

Constantly evolving society and cumulating amount of knowledge opens new possibilities for education. Understanding and adopting many theoretical principles and practical skills are important goals for every learner. Besides learning pieces of information and practices, learners should be provided with efficient learning skills that enable them to explore knowledge both independently and in collaboration addressing their personal educational needs.

Learning is a process and phenomenon that can be approached and analyzed from various perspectives. There are many competing and complementing *learning theories* that try to explain principles of learning and suggest recommendable activities for practical educational work. This manuscript proposes new methods and frameworks for computer-assisted learning that can be applied in various educational contexts for adoption and management of knowledge and can be combined with alternative supplementing learning activities and educational technology. The proposed new methods rely on interactive *software modules* (software components) that aim to personalize collaboratively created knowledge structures to address needs of the learner. The development of new methods is motivated by previous research about properties of learning process and earlier promising results concerning intelligent tutoring systems and collectively built knowledge resources including the Wikipedia online encyclopedia (<http://www.wikipedia.org>).

Our research approach relies heavily on computer science and software systems and we present results based on eight peer-reviewed conference articles discussed in dedicated chapters and referenced to by notations [P1], [P2], [P3], [P4], [P5], [P6], [P7] and [P8]. The new methods have been implemented as software modules programmed by the author as prototype tools. Various *user tests* have been carried out by the author with prototypes to verify suggested pedagogical gain of using new proposed computational methods. The benefits and challenges of the educational use of the methods have been analyzed. To position our research and to highlight many underlying multidisciplinary properties of learning that motivate development of our proposed computational methods and frameworks we provide a relatively broad synthesis about previous related research in Chapters 1–3 and Chapter 11. We want to emphasize that in the synthesis about previous related research we naturally could not cover all possible branches of literature but we tried to focus on such aspects that we considered essential to motivate our own proposals. Furthermore in the spirit of open data movement we wanted to supply this publication with relatively detailed collection of data that we gained from literature and our own experiments. Thus we want to offer to the reader a possibility to evaluate our data broadly in detail to get a better overall picture of

different conceptual resources that we are analyzing and comparing. We think that detailed large tables enable to see better also such faint but still important properties of listed data that can occur in so called long tail of distribution. In addition by supplying this publication with relatively extensive data we want to facilitate and encourage possible future research exploiting this data to be used for example in comparative analysis.

1.1. Addressing the needs of the learners

To support human wellbeing in constantly developing modern societies finding new innovative educational working strategies has been considered important (Ainoa et al. 2009).¹ It has been internationally recognized that systematic coordinated efforts are needed to enhance development of educational systems. Following the Millennium Summit of the United Nations in 2000 all 189 member states at that time committed to support achieving eight specific Millennium Development Goals by 2015 including to achieve universal primary education (other seven goals being: eradicating extreme poverty and hunger; promoting gender equality and empower women; reducing child mortality; improving maternal health; combating HIV/AIDS, malaria and other diseases; ensuring environmental sustainability; and developing a global partnership for development) (United Nations 2014). Funded by the European Union, the project Time for a New Paradigm in Education: Student Centered Learning (T4SCL) carried out in 2009–2010 by the European Students' Union and Education International (a global federation of teachers' trade unions) highlighted the need for resources to materialize a paradigm shift in educational practices (Attard et al. 2010). This paradigm shift should promote replacing conventional learning (or traditional learning) with student-centered learning.

Conventional learning typically considers the students as passive receptors of information lectured by teacher whereas *student-centered learning* (also called as learner-centered learning) typically gives to the students the freedom and responsibility to form their own learning paths by active participation in educational process (Jonassen 2004, 704-706). Here *learning paths* can be seen as entities that describe a structure of actions a learner has to perform in order to attain a competence or a competence profile (Janssen et al. 2008). In fact, interest in favoring student-centered learning has obviously influenced that educational activities are nowadays often described from the learner's perspective rather than from the teacher's perspective and furthermore, it seems that when talking about education, the concept of teaching—having historical

¹ Despite of relatively long and vulnerable infant period *human species* have gained their exceptional survival in the evolution with their ability and eagerness to learn and to be creative. An important factor for survival and cultural development of the human species has been the altruistic human tendency of *sharing knowledge* with community members and *conveying knowledge* to future generations within folklore. This has been enhanced by establishing writing systems, libraries, printing and school system. The success of civilization largely relies on the rise of scientific worldview, cultural exchange, expeditions as well as foundation of school and university system with systematic organization of education and scientific work. To address principles of sustainable living it is important to see how life-long learning can be naturally incorporated to emerging and evolving future forms of working and education that prepares individuals to work.

connotations about relatively passive students—is sometimes replaced with the concept of learning to specifically emphasize the learner’s role in adoption of knowledge (Barr & Tagg 1995).

Theories that try to explain learning process and try to help to develop advanced learning methods, possibly enhanced with technology, have often addressed the importance of taking into account how individual needs of the learner could be well addressed in learning activities ((Jonassen 2004, 704) referring to (Wagner & McCombs 1995)). Research approaches considering the learner’s individual needs has created varied theoretical frameworks dealing with so called *learning styles* (Jonassen 2004, 375-376) which have proved to be very popularly applied by educators and offering significant area of consulting business claiming to be scientifically rooted (Pashler et al. 2009). In a broad comparative analysis Coffield et al. (2004) pointed out the great challenge of trying to integrate diverse results about suggested learning style models and whether models relying on learning styles can really offer a promising theoretical approach for supporting learning. They argued that many educators have noted that traditional teaching methods based on transmission by the teachers and assimilation by the students are not working well with all students and thus there has naturally emerged a strong need among educators to try new techniques that are introduced and claimed to help reaching learning goals easier and addressing varied types of students.

Thus even if the actual validity of many learning style models remains yet to be verified there seems to be a strong motivation for developing and experimenting with educational theories relying on learning style models (Jonassen 2004, 656). Based on literature review, Pashler et al. (2009) claimed that they did not find adequate evidence to justify incorporating assessments based on learning style models in general educational practices and argued that it is important to identify teaching techniques that have experimental support and to abandon widely held beliefs if they appear to lack empirical support.

It has been suggested (Jonassen 2004, 652) three major classes of *adaptive instructional systems* that rely on macrolevel adaptation (selecting only a few components of instruction such as goal, depth of content and delivery system), adapting specific instructional procedures and strategies to specific student characteristics and microlevel adaption (diagnosing specific learning needs during instruction and providing guidance addressing them). It has been argued (Jonassen 2004, 655-669) that since previous research has identified difficulties in matching students having a certain set of characteristics to a certain instructional method as suggested by aptitude-treatment model, there has emerged optimistic interest in micro-adaptive instructional models that instead of pre-task measures aim to use on-task measures to make adaptive instructional decisions during instructional process. Micro-adaptive instructional systems form a diverse collection of approaches that can be considered to range for example from programmed instruction to intelligent tutoring systems supplied with artificial intelligence (Jonassen 2004, 661). Inspired by intelligent tutoring systems since 1990s adaptive hypermedia systems have been actively introduced (Jonassen 2004, 667).

Our research presented in this doctoral dissertation can be seen as an effort to contribute to long history of educational research dealing with such themes as programmed instruction, adaptive hypermedia systems. It has been argued (Jonassen 2004, 545-569) that theory of *programmed instruction* originates largely from suggestions of Burrhus Skinner to develop traditional teaching practices by scheduling and designing learning material and arranging it in developmental order that may exploit linear or branching structure, using mechanical devices to give feedback to the learner and using student performance data to make revisions ((Skinner 1954); (Skinner 1958)). In addition it has been argued ((Jonassen 2004, 668) referring to ((Park 1983); (Eklund & Sinclair 2000))) that adaptive hypermedia systems should rely on principles of hypertext links, have a domain model and modify visible or functional parts of system according to information stored in a user model.

1.2. New methods to explore network of educational knowledge

A *learning environment* can be considered as a social-psychological context where learning can happen ((Newhouse 2001) referring to (Fraser & Walberg 1991)), and in *computer-supported learning environments* computers have an important role to maintain the environment or to support learning of student in Vygotskian style ((Newhouse 2001) referring to ((DeCorte 1990); (Mercer & Fisher 1992); (Mevarech & Light 1992))) (more about Vygotsky is discussed in Subchapter 1.4).

There seems to be somewhat confusing and partially overlapping variety of definitions for terminology concerning computer-assisted learning, including computer-assisted instruction, computer-based instruction and web-based training. It has been suggested ((Parr & Fung 2000) referring to ((Cognition and Technology Group at Vanderbilt 1996); (Wright & Marsh II 1999-2000); (Schacter 1999a); (Schacter 1999b))) that originally *computer-assisted instruction* has relied strongly on drill and practice programs whereas *computer-assisted learning* relies on more advanced programs such as tutorial instruction and recording and management of performance, and *computer-based instruction* has been characterized as giving emphasis on individualization of learning process. *Web-based training* (or *online learning*) relies on instruction accessed via Internet with web technology ((Haag & Fischer 2011); (Koller et al. 2006)). *Intelligent learning systems* can be defined as a computer-based system that provides educational content of curriculum in personalized form to students and manages learning processes ((Parr & Fung 2000) referring to (Brown 1997)). *Technology-based learning* (or *e-learning*) can be considered as learning carried out by electronic technology, thus covering for example various web technologies (such as webcasts, video conferencing and chat rooms), satellite broadcasts and cd-rom (Koller et al. 2006).

A general goal in *computer-assisted learning* (also called as computer-supported learning) has been to support learning with *computational methods* that are typically

based on some kind of automation.² It has been argued (Jonassen 2004, 104) that design and performance of instruction need to be integrated to implement cognitive principles in methods of educational technology and this can be beneficially done by developing learning environments that adapt instantly to the learner's current needs and tendencies but the environment does not need to be intelligent itself, instead the environment should be responsive to the learner's intelligence thus determining the best ways for him to learn.

Fischer (2000) argues that in education innovative use of computers has relied on two main approaches that are intelligent tutoring systems and interactive learning environments. Fischer argues that *intelligent tutoring systems* have strength in teaching basic concepts when introducing a new domain but have weakness in supporting learning on demand to relate teaching to the learner's actual problem situations, and *interactive learning environments* have strength in supporting autonomous learning in learner's actual situation without system-controlled order but have weakness in supporting learner to identify mistakes and loss of organization. Fischer suggests that *domain-oriented design environments* can address the challenges of intelligent tutoring systems and interactive learning environments so that they support learning on demand and self-directed learning as well as benefit from contextualized tutoring (getting influence from intelligent tutoring systems) and end-user modifiability (getting influence from interactive learning environments).

Unfortunately, many earlier computational tools developed to support learning have suffered among other things from limited possibilities for both *personalization* (i.e. addressing learner's personal needs) (Huang et al. 2007) and *updating* (i.e. changing provided learning content to keep it up to date) (Pahl 2003). Some of the systems have enabled increasing and updating the knowledge structures of the system but it has often been possible only manually with a laborious process and resulted in each learning community to build redundantly their own educational contents without ability to combine more efficiently their efforts (Dagger et al. 2005). Challenges of updating have existed especially with workstation-based, standalone and offline applications developed before and without the modern dynamic online connectivity and cloud based architectures typically provided through Internet.

Also in the domain of hypermedia-based systems an increasing emphasis has been given to develop adaptive systems. Despite of individual needs, a typical traditional hypermedia learning environment has provided to every learner relatively similar educational contents and this means that knowledge structures provided by the system and linking them to the previous knowledge structures already possessed by the learner has been permanently inflexibly determined when the system has been created (Jonassen 2004, 667). It has been argued (Jonassen 2004, 667) that an adaptive hypermedia system aims to offer a presentation of learning topic so that it adapted to the

² While having an aim to support learning with automation, it is interesting to note that this aim touches closely the fundamental driving forces of computer science in general. A general motivation for evolution of *computer science* has been an aim to provide automation for processing information through methods of computing and organizing data but still today many early expectations of developing truly intellectual human-like—or even superior—computers have remained largely unattainable.

learner's prior knowledge (De Bra & Calvi 1998) and a set of most relevant links to explore (Brusilovsky et al. 1998). Prediction made in 1995 about future of hypertext in 2005-2015 (Nielsen 1995) suggested emphasis on for example very large hypertexts and shared information spaces, need for carefully edited authoritative hypertext resources possibly supplied with voting as well as automatic guidance to help educational navigation in hypertext. Background of adaptive e-learning research can be considered to form three generations since early 1990s ranging to cover from adaptive educational hypermedia systems to adaptive educational hypermedia systems and then integrating adaptive hypermedia into regular educational processes ((Ghali 2010) referring to (Brusilovsky 2004)).

Anyway, it seems that the best benefits from computer-assisted learning can be gained if technology is used as a complementing and supplementing resource for learning and thus computer technology should not be given dominating but instead supporting role. Based on multiround iterative survey done with preschool experts to identify key criteria for choosing Internet activities that enable developing cognitive, kinesthetic and affective competencies in a preschool child resulted in criteria that highlighted the need for interactive, developmentally appropriate activities that are not necessarily offered through Internet (Lombardi 2011). A meta-analysis of 50 studies (Means et al. 2010) found out that learning results were modestly better in online learning than in traditional face-to-face learning, and combination of online and face-to-face learning had a bigger advantage in respect to face-to-face learning than only online learning, and furthermore effects were bigger in instructor-directed or collaborative online learning than in independent online learning.

Computer-based technology has been seen as a promising solution to offer new kind of support tools for independent personalized learning that is free from many time and location constraints. In educational technology typical challenges have been dealing about how to implement *interactive adaptive visualization* about a desired educational content to address the learner's current personal needs. Here it should be noted, that term visualization is used in this context to cover besides visual illustration (i.e. illustration perceived through eyes) also *non-visual forms of illustration* such as auditory (i.e. hearing-based) and tactile (i.e. touching-based) sensory communication.

In this dissertation we introduce a set of computational methods that we have developed to support learning. We have combined these methods into a collection of *software modules* that can be used together to various educational purposes, especially for exploration of online resources but also for offline-use if needed. The methods can also be used as separate individual components that can be added as plug-ins to other implementations of educational software. This requires that those other software units support data communication with the components through their interfaces. Our research tries to find answers to persistent challenge of generating *guidance* for personalized exploration in knowledge structures and supporting *agglomerating* and *linking* pieces of knowledge in a pedagogically fruitful way.

Our proposals are inspired by adaptive and efficient link structures that have properties of so called *small-world networks* and *scale-free networks* and even both of them together. Small-world topology emerge in a diversity of natural processes: both

structurally and functionally in human brain networks (Wang et al. 2010), social networks (Uzzi et al. 2007) as well as in wikis that are collaboratively edited web sites (Mehler 2006). Bullmore and Sporns (2009) mention that some studies indicate scale-free properties in functional brain networks ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008)) and some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)). Our work largely relies on exploiting knowledge structures of the *Wikipedia online encyclopedia* (<http://www.wikipedia.org>), the currently largest wiki and online encyclopedia freely available and holding properties of small-world network (Ingawale et al. 2009) and furthermore properties of scale-free small-world network ((Zesch & Gurevych 2007); (Masucci et al. 2011)).

The set of methods and frameworks introduced in this dissertation aims to support learning with the following complementing emphasis:

- identifying and addressing distinctive roles of collaboration typical for each personal individual participating in complementing collaborative learning process that can produce cumulatively a mutually agreed knowledge structure with intuitive visualization
- exploiting the knowledge structure of the Wikipedia online encyclopedia to provide guidance for promising educational exploration in new knowledge for the learner
- generating adaptive visualization with concept maps about the exploration in the Wikipedia along promising learning paths
- using statistical features concerning the Wikipedia articles to suggest promising different learning paths for exploration emphasizing different characteristics in the educational domain
- letting the learner to get simultaneously parallel alternative recommendations for exploration enabling her to build diversely branching knowledge structures according to her needs
- using the consecutive temporal versions of Wikipedia articles' edit history to suggest promising learning paths showing evolution of conceptual structures
- building a wiki-based cumulative repository of concept maps that can be used collectively for various educational purposes with learner-driven criteria
- using knowledge structure of the Wikipedia to generate promising learning paths to link new entities of educational knowledge to the learner's prior knowledge, supported with augmenting collective and everyday knowledge
- generating learning paths in conceptual networks adapted from hyperlink network of the Wikipedia in a sequential process having tailored variation and repetition computed based on theory of spaced learning and reaching vocabulary sizes suggested to suffice for reasonable comprehension in human communication with cumulative vocabularies tailored for consecutive levels of language ability

In this dissertation chapter by chapter we explain underlying motivation for the methods we have developed and the way their implementation has been carried out with a

software systems approach. With experimental results gathered in real educational setting with groups of learners we aim to give convincing verification for suggested pedagogical gain of using the methods.³ Based on our research described in publications [P1]-[P8] we cumulatively build a complementing collection of methods that can be used in two general educational frameworks that we propose in publications [P7] and [P8] and discuss in Chapter 12. This cumulative modular structure of our research and this dissertation aims to synthesize our findings and to offer inspiration for future research and application of gathered insight in practical everyday educational work in any form of life-long learning both individually and collaboratively.

1.3. Research questions and research methodology

Our research relies on developing educational methods that are inspired by the collaboratively maintained knowledge structure of the Wikipedia online encyclopedia and representing, exploiting and mimicking its features and content. Due to the Wikipedia's many unique characteristics (including its popularity, coverage and constant updates) we consider the Wikipedia to offer much more than just a quick encyclopedic reference for factual information. Instead, we think that the Wikipedia can provide a promising example, model and analogue for *construction of human knowledge* that can be applied in varied scales and context of life. Especially we find it fascinating to suggest that the processes that can be identified and modeled in the building and accessing the Wikipedia can provide a promising example, model and analogue for thinking in an individual human mind and how learning process can happen through adoption, chaining and agglomeration of pieces of knowledge with a kind of network structure.

In the current era of networking and popularity of social media, *participatory design* has appeared as a promising way to collaboratively build resources by volunteers to serve themselves and encountered needs. A closely related variation is *crowdsourcing* that refers especially to commercial exploitation of ordinary people by engaging them to activities that essentially help to model and track customer activity patterns and to build brand visibility in the media through embedded or viral marketing. Some of the traditional challenges that emerge in ordinary efforts to motivate people to work individually and collaboratively can be also present with participatory design and crowdsourcing but they can be often overcome with suitable rewarding schemes or even indeed due to the absence of rewards that gives a specific honorary status for the voluntary work.

Our research aims to exploit the knowledge structures built in wiki style that form the Wikipedia. We decided to exploit especially the Wikipedia since apart from many other collaborative online projects it seems to have been exceptionally successful in

³ To promote open distribution, the *methods and software modules* supporting learning that we have developed and implemented in our research described in publications [P1]-[P8] are meant to be public so that details of used research methodology, computational models, program code and data structures are available from the author by request.

maintaining high popularity in general reading access—and what is even more delighting—maintaining high volunteer activity in writing, editing and other maintenance work as well. Thus the Wikipedia has addressed a crucial requirement: how in the first place to get people involved to contribute and then later, indeed, to keep them constantly updating by reviewing and further editing. It seems that the fundamental principles of free access and editing has enabled the Wikipedia to avoid challenges that purely commercial corporations face when trying to convince people to spend time voluntarily with their proprietary products.⁴

To address various challenges concerning supporting learning with adaptive collaborative knowledge resources and recommendation systems based on them, we discuss in this dissertation possible promising solutions that take inspiration from the following *main research question*:

What kind of methods are promising for developing computer-assisted collaborative knowledge management systems that aim to support cumulative exploration and adoption of new knowledge addressing the learner's personal needs in various contexts and collaborative processes and that can exploit knowledge resources of Wikipedia online encyclopedia?

This main research question covers a large range of issues concerning computer-assisted learning as well as theory and practice of educational work. Therefore we have decided to divide the main research question into several subquestions that we expect to be possibly easier to address efficiently. Some researchers especially recommend formulating part of the research questions along the research, not only in advance, to support making discoveries (Brewer & Hunter 2006), and thus we have set some subsequent goals for our research based on our prior results. Our research has specific emphasis on *computer science and engineering* and developing *software systems* that can be applied to address educational needs in various learning scenarios. Thus we recognize that our research can not exploit and combine all possible methodology introduced in other research fields that are related and affiliated to learning and education. Methods and models developed in our research are strongly motivated and inspired by findings in other fields of research, including for example mathematics, psychology, neurology, cognitive science, pedagogy, sociology and organizational management, but our inherently strongest field of expertise and contribution is positioned in the field of computer science and its applications to education.

Main themes of our research are further explained in Appendix B by formulating a list of questions that divide the main research question into more manageable units (see Appendix B). To find some answers to the main research question we needed to select a suitable *research methodology* that takes into account the current research field with its traditions and the context in which our research was going to be applied. Since this dissertation is carried out in the field of computer science with some influence from

⁴ We think that it might be the Wikipedia's very humane and noble goal of offering a free extensive knowledge resource for everyone that has made volunteers devoted to contribute to its building so willingly. In a survey covering 4930 Wikipedia editors (Wikipedia editors study 2011) it turned out that 69 percent of editors could agree that starting to contribute to Wikipedia was motivated by liking the idea volunteering to share knowledge and 71 percent editors could agree that this same reason motivated to continue contributing.

fields of software systems and educational technology, our chosen methodology emphasizes development of new *computational models* and their implementations as functional *prototype software modules* that are applied in real social user environment. We have done our best to take sufficiently into account diverse prerequisites and requirements that belong to complementing multidisciplinary fields of our research.

Engineering research is strongly guided by *empirical and experimental work*. However, since computational models have a *mathematical and analytical motivation* there is also a strong aim to make theoretical and logical contribution in research of computer science. Our current research has tried to balance fruitfully between theoretical and practical aspects of engineering research. We aim to develop computational models that can support learning and to reach this goal it is important to try to bring theoretical results sufficiently applied to practical life immediately or at least in the very near future.

The computational models we propose for offering *recommendations* to the learner about promising learning paths are somewhat constantly evolving models and can be considered to contain some kind of learning properties typically belonging to *artificial intelligence*.⁵ Furthermore, it needs to be noted that computer science literature refers often to concept of “*learning models*” meaning typically generation of predictive *probabilistic models* based on input data available from an observed phenomena that can belong to almost any field of life. However, in our research as well as in general terminology of pedagogy and educational technology, concept of “*learning models*” means typically *tailored schemas* identified to successfully represent recommendable human learning processes, often emphasizing certain perspectives and activities considered especially useful for the learner’s education.

In this dissertation we use rich synonymous terminology when referring to educational technology and computer-assisted learning in general. Thus we often follow relatively generally agreed definitions, such as those we mentioned in Subchapter 1.2. If we have not identified a reason to differentiate specific meanings, we use relatively liberally concepts of computer-assisted learning, computer-supported learning, e-learning and resembling expressions with the approximately same meaning.

Since our research focuses on modeling operational principles in complex human-based collective cognitive activities we have tried to incorporate to our engineering oriented research also *multidisciplinary influence* from other related research fields. To keep our research in a compact and manageable form, we have been forced to make hard decisions about research methodology and perspectives that can be included and

⁵ Due to common terminological confusion in computer science, it needs to be clarified that our research about “learning” primarily refers to learning in the context of education. When talking in this thesis about learning we typically mean a *human learning process*. Thus learning dealing with so called “learning algorithms” in the context of *artificial intelligence* that typically aims to mimic neural processes for example to train models of pattern recognition for computer vision are not primary subjects of our research. However, we think that our proposed models hold some such characteristics that they can actually be considered to enable some kind of *autonomous learning on the algorithmic level* of our models. For example, our research relies on assumption that typical learning activities proceed cumulatively in a process of chaining essential pieces of knowledge in fruitful ordering in respect to the learner’s personal needs.

covered in this dissertation.⁶ We hope that our current research can serve as an inspiration for future research and encourage others to continue the work despite the evident challenges and incompleteness inherent in this research field.

1.4. Modeling learning processes

In respect to diverse and competing spectrum of educational theories, we have decided to consider in our work the learning process in the light of few popular and respected interpretations of *learning theories*. Learning theories try to scientifically explain what actually happens in learning. Like theories in general, also learning theories are in constant evolution and it seems that various trends emerge and disappear and old ideas become recycled after some time has passed.

Baggio (2009) claims that four learning theories are relevant when considering creation of cognitively supportive multimedia learning environments and these four are behaviorism, cognitivism, constructivism and humanism. Descriptions given by Baggio mention that *behaviorism* observes learning to emerge as a change in observable behavior resulting from experiences, *cognitivism* observes learning to emerge when learner processes gained information to build a mental representation of it, *constructivism* observes learning to emerge when the learner actively discovers knowledge in interaction with the world and *humanism* observes learning to emerge through a learner's desire to reach fulfilled human qualities thus enabling to making positive decisions.

Taking into account ontological and epistemological assumptions, units of analysis and the mind-body relation, Schuh and Barab (2008) have proposed a classification that consists of five major psychological perspectives providing a foundation for learning and instructional theories: behaviorism, cognitivism, cognitive constructivism, sociocultural/historicism and situative theory. In brief, *behaviorism* has been seen to focus on objectively observable behaviour of learning, *cognitivism* to focus on inner mechanisms of human knowing and thinking, and *cognitive constructivism* to focus on a process approach in which the learner actively constructs ideas and concepts, *sociocultural/historicism* to focus on interaction between individuals in a society, and *situativity theory* to focus on situations in which individual act.

Schuh and Barab (2008) name one influential learning theory for each of these perspectives: behaviorism is influenced by Skinner's operant conditioning (Skinner 1938), cognitivism by Ausubel's meaningful reception learning (Ausubel 1977), cognitive constructivism by Piaget's scheme theory (Piaget 1936/1952), sociocultural/historicism by Vygotsky's zone of proximal development (Vygotsky 1978) and situativity theory by Lave's and Wenger's legitimate peripheral participant (Lave & Wenger 1991). Furthermore, Schuh and Barab (2008) give one example of

⁶ We recognize that our research can represent only a fraction of the issues concerning computer-assisted learning but we hope that our work can fruitfully complement previous work by helping to increase understanding about the processes involved in learning and how learning could be supported with computational methods.

instruction theory or method for each of these five psychological perspectives: behaviorism is expressed in programmed and computer-aided instruction, cognitivism in Gagné's conditions of learning (Gagné 1985), cognitive constructivism in discovery learning, sociocultural/historicism in reciprocal teaching or scaffolding and situative theory in anchored instruction.

Our research relies on an assumption that computer-assisted learning should try to fruitfully take influence from all of these five major categories listed by Schuh and Barab (2008), and probably even from further complementing categories since each categorization alone typically have their own constraints. Thus we think that adaptive learning tools should for example exploit monitoring the learner's activities, let the learner to follow her intuition, support the learner to build constellations about her conceptualization, enable fertile collaboration in a learning community and make the learner engaged in solving realistic problems.

In a meta-analysis covering 658 studies on game-based learning, Wu et al. (2012) found out that only 91 studies were based on one of four learning theories they aimed to identify so that 48 studies were considered to be based on constructivism, 25 based on humanism, 17 based on cognitivism and 15 based on behaviorism, and among representatives of behaviorism 9 relied on direct instruction, 3 on programmed instruction and 3 on social learning theory.

Cognitive science refers to interdisciplinary research studying mind as an information processing entity and being influenced by many related traditional academic research fields. An important aim in this research domain is to develop models capable of explaining consciousness (Blanquet 2011). Our work takes inspiration from cognitive models concerning *social cognition* which deals with questions about how mental processes and learning can be influenced by collaborating with surrounding social group ((Bargh 2006); (Frith & Singer 2008)). Early work concerning how group processes affect mind has been identified in a cognitive model based on *schemata* that enable relating new experiences against the background of earlier experiences at the intersection between organism and its environment (Wagoner 2013). Processes of social cognition have been also approached with *attribution theory* suggesting how people explain causes behind different behaviour and events (Oghojafor et al. 2012). *Bayesian theory* extends traditional logical reasoning to evaluating probabilities of the truth of the hypothesis that can be sequentially (iteratively) updated with new relevant data (Gill 2007). The formulation of Bayesian probabilities can be seen to be based on either *subjective belief* of or on the *objective state* of the knowledge. Complexity of many Bayesian methods can be managed computationally with approximations based on *Markov model*, including *Markov chain* for cases with fully observational system states and *hidden Markov models* for partially observable system states.

To ensure good usability for *user interfaces* of systems so that they can help the users to reach their goals based on their intentions Li (1999) suggests that the design of user interfaces should enable both an easy way of action and a natural way of action with specific design criteria. To address the easy way of action, the design criteria should include easy perception and less attention (proper amount of information with 5–

9 chunks, easy detectability and recognizability, visualization of artifacts, desired affordance, visual guidance, and economy of perceptual processing), easy cognition and less effort (to make the behavior of artifacts visible, to find consistent mapping of human action on computer operation, to offer understandable and rememberable meaning of information, to employ everyday logic and heuristic way of problem-solving, and to make memory easily), easy physical performance (direct perception, perceptual-motor coordination and easy learning) and action guidance (concerning intention, reparation, plan, implementation and termination). To address natural way of action the design criteria should include natural context, language and information, natural ways of perception and attention (coordinated coupling of information, perceptual desires and modalities), natural ways of cognition (multiple relations between desired mental processes and information, immersion and learning) and natural ways of physical performance (natural input and interaction devices and offering natural environment).

Our research tries to develop computational methods to assist learning and managing conceptual knowledge structures. Theories about concept learning are diverse and disagree about many fundamental features of learning process. *Concept learning* (also referred to as concept attainment or concept formation) is a process that deals with learning conceptual categorization and concept learning has been explained with various competing theoretical frameworks, including for example rule-based theories, prototype theories, exemplar theories and Bayesian theories (Goodman et al. 2008). Bruner et al. (1956) offer one of the early works promoting categorization as an important aspect of cognitive processes by exploring the factors concerning how thinking involves grouping of things.

Perceptual categorization has been often explained with *single-system models* assuming that categorization is based on existence of a unique representation (Ashby & Gott 1988) and one popular type of single-models are *exemplar models* which assume that category exemplars are stored in a person's memory classifying new stimuli according to their relative similarities to the stored exemplars (Medin & Schaffer 1978). An alternative explanation for perceptual categorization has been *multi-system models* assuming an interaction between two distinct category representations relying on explicit representation based on simple rules and implicit representation based on exemplars or more complex rules (Ashby et al. 1998). *Prototype theory* assumes that categorization relies on idealized prototypical representations defining critical features of category and sufficient matching is used for classification of new stimuli (Rosch 1973). In categorization of concepts it has been suggested that *similarity between two representations of stimuli* can be determined based on their distance in underlying psychological space and that the value of similarity possibly decays according to function e^{-cd} (Shepard 1987) where d is distance between representations and c is an assistive parameter, or according to similar function with d raised to power of 2 (Nosofsky 1986).

Research has identified neural activities correlating with some of the suggested psychological models about categorization, for example in *functional magnetic resonance imaging* it has been observed activation of medial temporal lobe that is

consistent with two predicted psychological processes enabling exception learning which are item recognition and error correction (Davis et al. 2011). In perceptual categorization task new stimulus dimensions can emerge when attention given to already existing dimensions do not help in separating stimuli from different categories and there is a simple linear combination of the existing stimulus dimensions so that stimuli belonging to opposite categories can appear at different ends of this emerging dimension. (Rodrigues 2008)

When trying to classify large collections of knowledge leads often to the *curse of dimensionality*, i.e. as the number of dimensions of data rises the contribution coming from single dimension decreases leading to fuzziness of the concept of the nearest neighbour. Network-based methods have been suggested for solving this challenge by converting high-dimensional data to low-dimensional codes (Hinton & Salakhutdinov 2006). We think that *neuroimaging* technology will likely in the near future offer a great resource for modeling processes of learning and thinking in general. For example, there have already been efforts to introduce low-cost electroencephalography for task classification in human computer interface (Lee & Tan 2006). Furthermore, it has been found recently possible with functional magnetic resonance to decode and reconstruct people's dynamic visual experiences relatively successfully (Nishimoto et al. 2011).

However, while waiting that the level of neuroimaging research results reach a sufficiently extensive, accurate and reliable solutions for modeling learning, we think that it is now still important to invest also in research relying on more traditional approaches and that is what we are doing. Therefore we see that we are currently living in a *transitional period* in the history of technological advancement and its applied research concerning learning. It is a responsibility for current generations to invest on very detailed biology based research approach that typically progresses slowly and can be expected to help profoundly only future generations in respect to understanding very well the human mental processes. However we think that there is also a strong need for more abstract and thus more rapid even if *robust research approach* relying on more conceptual abstractions of logic and psychology to develop methods that can quickly help current generations in understanding at least a little bit better than earlier the mental processes. Our research reported in this dissertation follows especially the latter approach thinking that with very good luck even this more robust approach can open some revolutionary scientific breakthroughs on a fast-track even if the risks of making a misinvestment of research resources might be much higher than with the former approach.

1.5. Main contributions and structure of this dissertation

We summarize here the main contributions of our current research work and at the same time describe the contents of the different parts of this dissertation:

Part I. Providing guidance in a network of educational knowledge

We introduce motivation for the dissertation and some issues related to background of the current research. The Chapter 1 gives a short introduction. The Chapter 2 discusses about the needs for computer-assisted education and Chapter 3 about collaborative educational processes in networks. In Subchapters 3.9–3.10 we introduce sample high-frequency lists and conceptual relationships generated by students and comparison of rankings discussed in publication [P9].

Part II. Collaborative building of link based knowledge representations in learning

Chapter 4 summarizes publication [P1] in which we introduce a computational framework to support collaborative knowledge building process and suggest computational methods to exploit cumulatively the complementing individual resources in learning to reach mutually agreed results combining text based discussion and concept mapping. Chapter 5 summarizes publication [P2] in which we introduce a computational method to assist exploration of collaboratively built hyperlink structure of the Wikipedia online encyclopedia represented with concept maps to gain pedagogically rewarding exploration. In Subchapters 5.3–5.4 we make comparisons of features of concept maps drawn by students, hyperlink network structure of the Wikipedia and exploration paths in hyperlink network of the Wikipedia discussed in publication [P9].

Part III. Generation of alternative personalized learning paths in link based knowledge structures by using statistical and historical data

Chapter 6 summarizes publication [P3] in which we introduce computational methods to generate alternative learning paths in the hyperlink structure of the Wikipedia relying on statistical features of articles and represented with concept mapping. Chapter 7 summarizes publication [P4] in which we extend the computational methods introduced in publication [P3] to support that the learner can simultaneously operate with parallel ranking lists of hyperlinks, the concept map construction emphasizes building diversely branching structures, and different consecutive temporal versions of Wikipedia articles can be browsed.

Part IV. Connecting and agglomerating entities of collaborative knowledge resources based on personal contributions

Chapter 8 summarizes publication [P5] in which we introduce a computational framework to support collaborative knowledge building process relying on a wiki based methodology with concept mapping supporting use of various educational games to explore and edit knowledge structures. Chapter 9 summarizes publication [P6] in which we introduce computational methods to help the learner's knowledge adoption with concept mapping relying on concepts of three perspectives of learner's knowledge, learning context, and learning objective that are connected based on hyperlink network of corresponding Wikipedia articles. In Subchapters 9.3 we make comparisons of features of concept maps drawn by students and exploration paths in hyperlink network of the Wikipedia discussed in publication [P9].

Part V. Forming new educational activities based on vocabularies, conceptual networks and spaced learning

In Chapter 10, we estimate effectiveness of potential of learning based on conceptual networks especially in respect to our proposed methods and also report a result discussed in publication [P9]. In Chapter 11 with an aim to better relate methods proposed in publications [P1]-[P6] and [P9] to fundamental characteristics emerging in any typical learning situation, we introduce a brief review about some fundamental characteristics that have been identified in previous research concerning human learning process and representation of knowledge. In Chapter 12, considering the review of fundamental characteristics affecting knowledge adoption just presented in Chapter 11, we suggest a combination of two new frameworks that we have synthesized based on methods we proposed in publications [P1]-[P6] and [P9], and these two new frameworks were proposed in publications [P7]-[P8]. Chapter 13 offers discussion covering some central themes of our research introduced in publications [P1]-[P9] and covered in previous parts of this dissertation are discussed and some recommendations for future work are provided.

Part VI. Additional resources

Contains a list of references and appendixes which include also reprints of the original publications [P1]-[P9] and supplements for publications [P2], [P5], [P6] and [P7].

To illustrate the evolution of our research and how eight individual research articles contribute to a greater entity of research results, the Table 1.1 characterizes some essential topics for developing computational methods to support learning and relationships between these topics in our work.

In our research we have defined general methods and perspectives to identify fruitful pedagogical ways to support learning and creativity. These efforts have maintained on rather abstract level aiming to categorize and conceptualize components and processes of learning. On the other hand, we have designed and developed practical tools to support learning. We have built new computational methods and frameworks based on previous models and research results found in the literature as well as based on our own innovation and experimentally gained modeling. Since our work primarily represents research of computer science and especially with some influence from fields of software systems and educational technology, we developed new methods and tools by designing and programming suitable data structures, user interfaces, web connectivity and operational logic.⁷

⁷ We have tried to maintain good options and possibilities for later updates, modifications and augmentation when designing and implementing our models and tools. We believe that prototyping, open-source movement and modularly distributed solutions are currently promising approaches to be used in software development work. Even if there are still supporters of more traditional philosophy of developing software we believe in relatively agile, improvised and collectively *gradually fine-tuned* development strategy. It seems for us more useful to launch software solutions in beta-testing phase so that the user community and research community can contribute in giving feedback in early phase and at the same time already also benefit of the use of the tools to increase quality of life.

Table 1.1. Evolution of the research carried out for this dissertation in respect to nine individual research articles showing some of their essential topics for developing computational methods to support learning and relationships between these topics.

<p>1. Collaborative learning framework (publication [P1]) 1a. collaboration to find agreement 1b. illustration with concept map 1c. tracking activities of learners 1d. guidance for personal roles and needs</p> <p>2. Exploiting knowledge of the Wikipedia (publication [P2] (supported by publication [P9])) 2a. relying on collective ontology for learning 2b. exploring hyperlink network 2c. personally traversed learning path (augments 1d) 2d. visualization of learning path as concept map (augments 1b)</p> <p>3. Statistical guiding in learning path network (publication [P3]) 3a. identifying various perspectives in respect to article statistics 3b. alternative rankings for traversable paths (augments 2b) 3c. selecting suitable perspective for traversals 3d. chaining knowledge in different perspectives (augments 2c)</p> <p>4. Building branching learning path network (publication [P4]) 4a. branching parallel learning paths (augments 3a) 4b. cross-linking knowledge of various complementing perspectives (augments 3d) 4c. exploring the latest version or temporal evolution of hyperlink network 4d. addressing cumulatively encountered knowledge and emphasis on definitions</p> <p>5. Building collective learning path network as a wiki (publication [P5]) 5a. identifying overlapping complementing learning path segments (augments 4b) 5b. defining recommendable learning paths (augments 1a) 5c. collective creation and evaluation of knowledge entities for learning 5d. enabling learning path networks for educational gaming</p> <p>6. Agglomerating pieces of knowledge (publication [P6] (supported by publication [P9])) 6a. diverse personal entities of knowledge 6b. connecting own knowledge to respected core knowledge (augments 3d) 6c. traversing shortest paths in focused and contextual knowledge (augments 2a) 6d. defining forms of basic learning games (augments 5d)</p> <p>7. Spaced learning of cumulative vocabularies (publication [P7]) 7a. generating learning paths in a sequential process 7b. tailored variation and repetition based on spaced learning (augments 6b) 7c. reaching vocabulary sizes sufficient for human communication (augments 5b) 7d. cumulative vocabularies tailored for consecutive levels of language ability (augments 4c)</p> <p>8. Cumulative exploration in conceptual network relying on growing vocabularies based on language ability levels (publication [P8]) 8a. identifying language ability levels for progressive stages of learning (augments 5a) 8b. generating cumulatively expanding hyperlink network connecting concepts of vocabulary (augments 2b) 8c. exploration of shortest paths between concepts having highest rankings and strongly rising rankings (augments 6c) 8d. guiding adoption of knowledge with cumulative conceptual networks with principles of spaced learning (augments 7d)</p>

Chapter 2. Needs for computer-assisted education

This chapter introduces current and emerging trends for the needs identified for developing computer-assisted education. There exists various parallel research fields and school of thoughts aiming to comprehend and model learning activities and support them with computational methods. We understand that the perspectives taken in our research are always to some extent subjective and deserve to be taken into critical consideration by the reader. However, we have tried to carry out our research in a systematic way with actions that are transparent and traceable by others. We aim to introduce our research in steps that enable the reader to achieve logical understanding of continuity ranging from ideas and formulation of models to implemented software prototypes and evaluation of experiments carried out with them.

2.1. New challenges for supporting education

Our research originates from the author's and the research community's notions that there is a need to develop adaptive computational methods that can support learning in respect to modern scientific theories about how to fruitfully support learning and exploiting new technological resources that have become available in everyday life. For example some suggestions have been created for a framework for research on technology-enhanced special education (Jormanainen et al. 2007).

To offer computational methods to support practical learning efforts of a learner several aspects need to be taken into account. We have listed here some relatively general aspects that we have considered important when designing computational methods to support learning:

- how the learner can be guided by the method following her educational needs
- how to address variety of different learning styles (or preferences) among learners
- how to address variety of prior knowledge of learners
- how to implement an intuitive user interface
- how to implement adaptive methods responding to the learner's actions
- how to keep the system that supports learning updated and popular
- how to efficiently create, store and represent knowledge needed in educational processes
- what kind of structure and processes are optimal for linking and agglomerating the pieces of knowledge in a greater entity

- how adoption of knowledge could benefit from tailored spacing and cumulative vocabularies
- how collaboration of learners and/or educators can be used for benefit in learning and how that can be supported
- how the performance and progress in learning can be measured and evaluated
- how the learning of the learners and research of educational technology can fruitfully support one and other

To develop some solutions that address these issues we considered important to position our ideas in respect to previous work carried out in the research fields related to education and computer science. For the development of *educational possibilities* of the whole humanity, it has been a very positive progress that along centuries and decades humans have systematically collected verified knowledge, documented it and started to distribute and exchange it in hand-writing, in print, by radio and television broadcasting and finally through multimedia-supported computer networks including the Internet. Public school systems have been established to provide centralized and qualified learning environments with professional teachers and making children exposed to broader spectrum of complementing facts and opinions than they could get solely at home.⁸

When making review about previous research and existing methodology and technology we witnessed a large variety of *different perspectives*, claims and beliefs that are applied in practical educational work (Torr 2003). There is a large variety of *different schools of thought* and it has remained hard to verify many of claims about recommendable practices for learning and even many of the most principal questions about learning remain open (Biesta 2007). For example, historical, cultural and religious opinions have largely affected the way children in different time and in varying locations have been taught.

Since the current youth generations have already inherently adopted new *behavioural language and grammar* to live with modern technology and they have populated the Internet as one of their playgrounds it is important to establish educational services that support using also these new resources and technical skills.⁹ No one can

⁸ To motivate our research in greater educational context, we think that skills of *critical thinking* and *freedom of thinking and speech* are essential for balanced evolution of civilized societies and these principles should be strongly encouraged among all school children and students. Progress of a society is strongly dependent on well-organized education that is offered to all of its growing citizens. Like previous generations have unselfishly developed and enhanced the chances for learning for current generations with the resources then possible, it is now our responsibility to continue the progress further by actively exploiting newly opened modern resources that have not been earlier available. Since scientific and technological innovations constantly change our everyday life and worldview it is important to develop learning into such direction that best addresses the new requirements and possibilities of the current time.

⁹ We think that a fundamental reform for the way of learning is enabled based on school children and students of today being born and living in a very different world than any earlier generations, and even very different than in their parent's youth 20-40 years earlier. On technological side, the mobile phones and Internet have revolutionized the way people can follow news, communicate in real-time, get entertained, do shopping and access various other online services. Wide-spread use of computers, embedded systems and smart phones in all areas of everyday life with a huge *variety of functional logic* and user interfaces ranging from mp3 players to social media applications have introduced to current

yet surely say if learning with certain technological devices and Internet-based services can necessarily provide better *overall learning experience* than for example a traditional classroom but at least it is still too early to condemn emerging applications of educational technology. In fact it seems that educational technology can serve at least as a fertile supplement to other methods of learning thus positively enhancing learning results.

2.2. New organization for educational activities

A great traditional challenge in education has been strong reliance on *classroom teaching* organized by a teacher following her personal devotion, commitment and agenda. Despite of planning work in advance, the teachers often face in the actual classroom setting a need to improvise due to many unexpected situations. Thus organization of educational content, methods to represent them and personal guidance of learners and allocation of resources are often carried out somewhat spontaneously by the teacher. Largely due to *cost-effectiveness* a group of learners has been typically taught by only one teacher at time. We think that there is a strong need for *computational methods* that can augment and broaden the traditional way to organize learning so that the learners could more independently carry out learning tasks and at the same time be supplied with useful automated personalized pedagogical guidance.

Like in many other fields of research, also in educational field many ideas suggested for development regularly face a renaissance, become reinvented or remain on hold since practical implementation appears challenging. We think that an influential early pedagogical framework that still maintains important value for development of new educational activities, giving valuable inspiration for our research as well, is Vygotsky's proposal of *proximal development* that relies on idea that with suitable aid from an educator a learner can gradually extend abilities beyond her unaided abilities (Vygotsky 1978). Gilbert (Gilbert 1978) has offered a behavior engineering model that defined behavior B as a product of repertory of skills P and environment E, i.e. with formula $B = P \times E$.

Since a teacher can typically give specifically *tailored guidance* only to one learner at time we think that automated support systems can enhance effective learning by helping the learner to avoid unnecessary moments of confusion and waiting.

Kuhlthau (Kuhlthau 1994) suggests that information search process can be represented with five *zones of intervention* addressing gradual levels of complexity so that each intervention zone is associated with specific level of mediation and education: self service (no direct intervention) is provided by organizer-type education with organizer-type mediation, single source intervention is provided by lecturer-type education with locator-type mediation, group of sources intervention is provided by instructor-type education with identifier-type mediation, sequence of sources

youth generations a new form of behavioural language and grammar about how to express oneself, how to communicate, how to search information and how to use purposefully a diversity of technical devices through their user interfaces.

intervention is provided by tutor-type education with advisor-type mediation, and process intervention is provided by counselor-type education with counselor-type mediation.

We think that to enable fertile learning educational activities should encourage the learner's *creativity* on various levels that could be monitored from different perspectives including such as output, process, person and environment (Medyna et al. 2009). For developing new computational methods supporting learning we think that there is a lot of unused potential in *collective knowledge* held by a group of learners. We think that there is a need for developing systems that could support processes in which learners could help each other based on their complementing pieces of knowledge and personal strengths that can be gradually collaboratively cumulated. In addition, we think that it is important to develop especially non-commercial support systems for education that are can be freely used by anyone and flexibly developed further if needed.

We believe that non-commercial support systems can possibly more naturally provide an *objective and neutral approach* to information than commercial support systems since there is no need to have any business model with compromising affiliations. Program code that can be freely distributed and exploited for developing new programs is called *open source*. Some important examples of freely distributable systems and applications that have enabled collaborative development of rich non-commercial modular ecosystems of information processing tools are Unix operating system Linux and Mozilla web browser. In a similar fashion we think that there is now a strong need to actively develop non-commercial modular ecosystems for innovative educational tools. Efforts to increase availability of free and easily usable educational solutions have a great impact for the beneficial growth of wellbeing for everyone but also especially for people living in developing countries, among challenged learners and in general people with special needs in all age groups.

In the recent and still continuing radical period of human history that has brought global connectivity with Internet to almost everyone's reach important actors have also been those who have begun introducing and distributing knowledge with *open access* (i.e. free unlimited access). Although there are still challenges in agreeing about fair ways to protect copyrights and defining reasonable economical compensation mechanisms for authors and publishers of creative work, it seems to be widely recognized that partly uncontrollable distribution of media content has permanently become part of online activity.

2.3. Identification of learning objectives

A significant and largely referenced yet also criticized classification about learning objectives is *Bloom's taxonomy* originating from a committee of educators (Bloom et al. 1956). Despite its challenges, the original classification work has valuably introduced systematizing efforts to educational research. The model suggests division of educational objectives into cognitive, affective and psychomotor domains. The cognitive domain, often considered the most essential domain of the model in respect to

traditional learning, is hierarchically classified to six levels of process. Going from the lowest to the highest level they are knowledge, comprehension, application, analysis, synthesis and evaluation. The learners should benefit from cumulatively proceeding from acquiring skills of lower levels to higher levels according to the model. Addressing each learning objectives, the model defines lists of verbs for assessment questions and it defines also suitable learning activities and media.

A later *revision of Bloom's taxonomy* was created trying to enhance earlier expertise in all domains of the model (Anderson & Krathwohl 2001). Among processes of cognitive domain the revised model puts synthesis on a higher level than evaluation and renames the levels to be remembering, understanding, applying, analysing, evaluating and creating. Furthermore, the revised model defines sublevels for the kind of knowledge to be learned and going from lowest to highest levels of learning they are factual knowledge, conceptual knowledge, procedural knowledge and meta-cognitive knowledge. With a matrix of two dimensions, cognitive process dimension and knowledge dimension, the revised model defines skills with a gradually increasing complexity and the learner should benefit from cumulatively proceeding from acquiring skills of lower levels to higher levels according to the model. Both dimensions of the matrix are further divided to sublevels to address more specifically diversity of educational needs. One of the main contributors for the original framework, Benjamin Bloom, has suggested that "Ideally each major field should have its own taxonomy in its own language—more detailed, closer to the special language and thinking of its experts, reflecting its own appropriate sub-divisions and levels of education, with possible new categories, combinations of categories and omitting categories as appropriate." (Anderson & Krathwohl 2001)

It has been considered that the educational needs *change along the age* of the learner. Especially when contrasting adults with children, adult learners have been seen as more autonomous and thus benefiting from having learning activities that sufficiently address their individual responsibility and motivation (Knowles et al. 2005). It has been suggested that human cognitive architecture relies strongly on five principles storing information in long-term memory, borrowing and reorganizing information of long-term memory, creation of novel information with randomness, limited capacity and duration of working memory to process novel information, combining working memory and long-term memory to link to and organize environmental information (Blayney et al. 2009). In adoption of knowledge it has been found that learners with lower expertise benefit from having elements of information being presented sequentially in isolated form whereas learners with higher expertise benefit from having elements of information being presented in full interactive form (Blayney et al. 2009).

2.4. Development of computer-assisted education

Developing computer-assisted education is typically motivated by an aim to enable flexible automated learning opportunities for learners and this aim has historical

background that carries heritage of scientific revolution and general optimism towards technological advancement.

Influential early contribution to currently popular learning theories has been given by Vygotsky (Vygotsky 1978) emphasizing that *social interaction* has a fundamental role in learning. Traditionally, especially in authoritative classroom context at school, educational practices have emphasized teaching in which an educator offers new information and practical examples that can be relatively directly and passively adopted by the learner and this type of education has been referred to as a *direct transfer model* of learning (Subrahmanyam & Ravichandran 2013). As an alternative for direct transfer model, it has been suggested that in educational process the learners should be provided with an active role instead of the more traditional passive role (Squartini & Esposito 2012). This has induced a need to develop and implement new kind of educational activities that encourage individual *exploration and creativity of the learner* but however it seems to be challenging to reliably verify if the new innovative learning methods can really offer actual educational gain when compared to more traditional methods (Archer & Hughes 2011).

Computer-assisted learning covers a broad spectrum of methods that aim to support learning with *information and communication technology* (ICT). Many alternative terms can be considered to refer to computer-assisted learning, including for example e-learning that is a term whose introduction has been credited to Jay Cross (Cross 2004) and can be interpreted to represent learning supported with information networks like Internet. In a multinational survey of Organisation for Economic Co-operation and Development (OECD) published in year 2005 many educational institutions reported that e-learning has a broadly positive effect on the quality of learning and teaching but *direct evidence of pedagogic value* has remained open question and adoption and use of computer-assisted systems has remained low in many areas, for example 6.6 percent of respondents reported institution-wide adoption of content management systems in 2004 (OECD 2005).

Computer-assisted learning can be seen as a part of long historical development that has aimed to offer learning opportunities with increased freedom concerning temporal and locational distribution of educational resources. Jónasson (Jónasson 2001) mentions based on previous research that already from year 1728 there are published magazine advertisements about *educational correspondence courses* (Holmberg 1986) but the first documented case of two-way communication has been credited to Isaac Pitman's shorthand writing course based on mailing postcards in 1840 (Verduin & Clark 1991). In addition, Jónasson mentions based on previous research (Verduin & Clark 1991) that the first currently known case of using term "*distance education*" has apparently happened in a catalogue of University of Wisconsin-Madison in 1892.

We think that significant inspiration for developing computer-assisted methods for knowledge management can be gained from proposal made already in year 1843 by Ada Lovelace (Lovelace 1843) that is considered to be among the earliest formal descriptions about *principles of an algorithm* and this proposal shows how long-lasting have been the efforts to develop analytical methods to automatically process knowledge

in ways that can be advantageous to human well-being. Some encouraging arguments of Ada Lovelace that motivate developing computational models are that:

“In enabling mechanism to combine together general symbols in successions of unlimited variety and extent, a uniting link is established between the operations of matter and the abstract mental processes of the most abstract branch of mathematical science. A new, a vast, and a powerful language is developed for the future use of analysis, in which to wield its truths so that these may become of more speedy and accurate practical application for the purposes of mankind than the means hitherto in our possession have rendered possible.” (Lovelace 1843).

Computers have been gradually introduced to schools around the world. The ratio of the number of students to the number of computers in American schools has been reported to decrease from 125:1 in year 1983 to 20:1 in year 1990 and then to 9:1 in year 1995 (Hamza & Alhalabi 1999). However, an influential early large computer-based instructional system that has been applied in educational work is PLATO system originating already from 1960's and developed at University of Illinois (Bitzer & Skaperdas 1968). Use of computer technology in learning activities at school has gained varied emphasis and still in the beginning of 21st century it has been often carried out without a systematic computer science curriculum (Tucker et al. 2003). Following the principles of traditional teaching methods *computer-based learning/training* typically refers to systems that offer self-paced educational tasks in a relatively linear way about a static educational content somewhat resembling reading a manual book and originally many solutions for computer-based training relied on local data and data content such as diskettes and cd-roms.

According to surveys, in 1994 about 35 percent of American public schools had access to the Internet, where as in 1995 about 50 percent of these schools had it (Carpenter et al. 1996). In 2009 in American public schools about 97 percent of teachers had at least one computer everyday located in the classroom and internet access was available for about 93 percent of these computers (Tice et al. 2010).

Even if the pace of supplying the schools with the technology varies in different locations around the globe it seems that during the last two decades a great number of learners at school became supplied with both an access to a computer and an access to Internet and this motivated creation of forms of *online learning* based on communication over the Web. Since the distribution and sharing of knowledge became easier, or at least got a new supplementary channel, with Web various *knowledge management systems* were introduced aiming to help building systematic knowledge resources and exploiting them online for learning (Toro & Joshi 2013). The evolution of web technologies and the increased use of personal communicational devices has opened opportunities for *mobile learning* trying to address ubiquitous possibilities for learning (i.e. enabling learning everywhere) and *computer-supported collaborative learning* trying to address learning by supporting organized collective complementing work among the learners (Hsu & Ching 2013). The phenomena of computer-supported collaborative learning has been very closely associated also with such terms as *e-learning 2.0* and *long tail learning* emphasizing the diverse use of social software modules including for example wikis, blog, podcasts and virtual worlds. An approach

called *blended learning* tries to find an optimal way to balance and integrate computer-assisted learning with practical and class-room based activities (Subrahmanyam & Ravichandran 2013).

A meta-analysis of 50 studies Means et al. (2010) found out that in educational experiments blended learning which combined online and face-to-face instruction outperformed conventional face-to-face instruction. However, it seemed that there is no direct evidence that this advantage was due to the online approach itself being a superior medium. In fact, online learning itself seemed to be about as effective as classroom instruction. In addition, conditions for compared online and face-to-face scenarios seemed to differ and it was likely that online approach included additional resources and used more time. Furthermore in this meta-analysis of Means et al. experimental evidence suffered from small sample sizes and there appeared to be little actual evidence gathered directly among elementary and secondary school students.

2.5. Learning by feedback and testing

Kirschner et al. (2006) argue that findings of previous research support direct strong instructional guidance rather than constructivism-based minimal guidance in instruction of novice and intermediate learners, and even for learners that have considerable prior knowledge strong guidance has been found to be equally effective as unguided instruction. When using computer-assisted learning environments, getting encouraging and appropriate *feedback* for the work done so far has been considered as an important factor to enhance learning results but immediate feedback can prevent the learner to acquire self-evaluation skills (El Saadawi et al. 2010). Despite its usefulness, feedback is typically provided after the learner has already made her action and there is need for assistance given already prior action that can be called as *cueing*. In a collaborative multimedia based learning experiment it was shown that both cueing and collaboration can positively influence learning outcomes and that the learners without cueing benefited most from additional collaboration (Hummel et al. 2006). Gureckis and Markant (Gureckis & Markant 2012) offer a review how process of self-directed learning can be motivated with both cognitive and computational perspectives thus contrasting human memory processes and machine learning methodology.

Transfer of learning refers to application of earlier learning experience in one context to a new learning experience in another context. Butler (2010) compared retention and transfer of facts and concepts when studying prose passages with repeated testing and repeated studying, and superior results were gained with learning process consisting of repeated testing. Marzano (2000) argues that during a grading period from practice session to practice session the amount of learning is large at first but later decreases so that power law can be used to estimate end score. He also mentions that this trend of *power law of learning* is introduced by Newell and Rosenbloom (1981) and that according to Anderson (1995) a power function formula $y=mx^b$ can be used to explain how much time in seconds (y) is needed to recognize precisely information that has been presented to a person after various amounts of exposures (x) concerning this

information, and parameters m and b can be defined to address a particular type of learning situation. Marzano (2000) suggests that same kind of power law formula can be used to estimate gradual increase of exam scores if student learns during a grading period containing intermediary exams each measuring adoption of new knowledge with equal coverage. Martin et al. (2011) showed experimentally how in adaptive educational systems learning performance curves relying on power law of practice can be used successfully in formative studies. However, it has been also suggested that exponential curves could be more appropriate than power law curves to represent learning performance ((Martin et al. 2011) referring to (Heathcote et al. 2000)).

In educational field, *multiple-choice questions* have been considered as a convenient way to implement easily automatically gradable tests but however it has been questioned how reliably they can measure the learner's actual understanding about a given topic (Kastner & Stangl 2011). Multiple-choice questions typically rely on the learner selecting the most promising option from a limited collection of alternative answers shown to her. In contrast, more open format of answering to tests rely for example on writing short essays or filling empty spaces in sentences without heavy constraints about writing style and this format can be called as *constructed-response questions*. Since grading cannot typically be performed automatically with constructed-response questions, they are often more laborious to implement, but anyway constructed-response questions have been often considered to test better the deeper understanding of the learner's understanding about a given topic (Kastner & Stangl 2011).

An experiment with vocabulary learning in a self-guided web-based language learning environment showed that constructed responses items had greater effect than the multiple-choice items on posttests about recall and recognition of the students (Chen & Chen 2009). In these results, higher cognitive load was reported with multiple-choice items and offering cueing did not give significant interaction effect between item types. Still, there have been efforts to identify links between two assessment metrics, multiple-choice questions and constructed-response questions, for example by addressing distinctive knowledge levels of Bloom's taxonomy but results have been mixed indicating that cognitive mechanisms involved in constructed-response questions appear to be much richer (Kuechler & Simkin 2010). However, there are also claims that constructed-response questions are equal to multiple choice questions that allow multiple responses and use scoring rule counting only correct responses (Kastner & Stangl 2011).

2.6. Learning based on recommendations

Recommender systems are computational systems that are used to filter relevant information items from a collection of information according to criteria matching the needs of the user. Recommender systems typically compare a user profile to some reference features and aims to estimate what new available information items the user might prefer to process next ((Ekstrand et al. 2011); (Ricci et al. 2011)). These reference

features can be based on various characteristics. Depending on the strategy, Burke (2002) has categorized recommendation systems into five classes that are: collaborative, content-based, demographic, utility-based and knowledge-based. *Collaborative recommendation* emerges from ratings given for items by similarly behaving other users and based on demographic data, *demographic recommendation* from preference of demographic classes possibly without a need for ratings, *content-based recommendation* from the features of the items according to the user's ratings of them, *utility-based recommendation* from the ranking of items by applying a utility function describing the user's preference, and *knowledge-based recommendation* by finding a match between the items and functional knowledge about the user's needs. In the last two cases, there is a challenge to actually identify suitable representation for utility function and functional knowledge.

Adomavicius and Tuzhilin (2005) consider that algorithms for collaborative recommendations can be categorized into two general classes, memory-based (or heuristic-based) and model-based, and according to them *memory-based algorithms* are heuristics which make rating predictions according to the entire collection of items that has been previously rated by the users, whereas *model-based algorithms* exploit the collection of ratings to learn a model that is then used to make predictions of ratings. Model-based algorithms rely typically on Bayesian models, latent semantic analysis, artificial neural networks, or machine learning methods, for example method called "k nearest neighbors". Recommender systems with the model-based approach are challenged due to its typical requirement of large samples of items to learn a model reliably. Drachsler et al. (2008) consider that in the near future large experimental samples can be hard to obtain for learning networks and thus they focus on memory-based approach. They also consider that memory-based algorithms can be categorized to *collaborative filtering techniques* and *content-based techniques*, and according to them collaborative filtering techniques can be *user-based*, recommending items rated by users having similar rating style, *item-based*, recommending items receiving similar type of ratings, or *based on stereotypes or demographics*, recommending items preferred by similar type of users, whereas content-based techniques can be *case-based reasoning*, recommending items similar to those the user has liked earlier, or *attribute-based techniques*, recommending items having attributes matching to the user profile.

2.7. Generating recommendations for fertile learning

In a survey comparing four different recommendation techniques and seven different hybridization strategies showed that among *hybrid recommender systems* promising are cascade hybrids and feature augmentation hybrids (Burke 2007). In *cascade hybrids*, recommenders have a strict priority so that the lower priority ones break ties in the scoring of the higher ones. In *feature augmentation hybrids* one recommendation technique computes a feature or features which are then used as a part of the input to the next technique.

Herlocker et al. (2004) have listed six typical types of *user tasks* supported by recommender systems and these six types include recommendations while user carries out other tasks, recommendations as a selected list of suggested items, recommendations as a complete list of related items, recommendations of a sequence of items, recommendations for the users without ulterior motives and recommendations while testing the system's capability. As a supplement to the previous list, Manouselis et al. (2011) name three user tasks considered particularly interesting in technology enhanced learning. They include recommendations of especially new items, recommendations of other users having relevant interests and recommendations of alternative learning paths through learning resources. Manouselis et al. (2011) also suggest identification of the *evaluation methods* that could be engaged to measure the effect of the recommender in a particular context of technology enhanced learning, specification of ways to measure the success of its various components and developing instruments to collect evaluation data in educational settings.

The nature of generated recommendations and even recommender systems can be evaluated with various measures and it has been suggested that the methods relying on collaborative filtering can have an advantage in contrast with the methods relying on content-based filtering when there is a need for recommending *serendipitous items* (i.e. surprisingly interesting items) for the user that she could not have found otherwise (Herlocker et al. 2004). Tintarev (2009) lists five features in respect to evaluation of recommender systems including accuracy, coverage, learning rate, novelty and serendipity and confidence (in relation to strength). In addition Tintarev (2009) lists four features in respect to evaluation of the impact of explanations given by recommender systems to motivate reasoning behind recommendations including accuracy metrics, learning rate, coverage and acceptance.

We briefly describe evaluation features based on overview of Tintarev (2009). *Accuracy* can be used to measure the proportion of items that have been classified correctly, and some possible measures are precision (inverse of false hit rate), recall (hit rate), F-score (a weighted combination of precision and recall), mean average error (weighted difference between prediction and rating of sets divided by number of rated sets) and receiver operating characteristics analysis curve (curve of recall plotted against variable 1 minus probability of an item being rejected for recommendation). *Coverage* can indicate how large domain of information items can be considered when giving recommendations (number of items for which recommendations can be made as a percentage of number of all items). *Learning rate* can indicate the quality of recommendations and since depending on statistical models the systems typically create asymptotically improving results. Learning rates can be computed in respect to overall system (quality as a function of overall number of ratings or users in the system) as well as single information item (quality as a function of number of ratings for this item) or user (quality as a function of number of ratings that this user has contributed), and often quality is measured with accuracy plotted against number of ratings. Although users typically appreciate some level of consistency (familiarity of provided recommended items), users also typically have a need to get recommendations that can provide items representing sufficient *novelty* (enabling such accuracy that new items are not too

similar or redundant with previous recommendations) and also items representing *serendipity* (items that are completely unexpected and furthermore not necessarily accurate but enabling system to learn more about users preferences). Often recommendation can be expressed a pair of value that are strength and confidence. *Strength* of the recommendation can indicate how much the system estimates that the user likes the current item. *Confidence* of the recommendation can indicate how sure the system is about the accuracy of the given recommendation. When measuring *acceptance* (satisfaction) of the user with the recommender system it is important to note that acceptance can be connected to various other measures (such as accuracy, novelty and diversity of recommendations) and be based on for example explanation components, recommendations, design and visualization.

Chapter 3. Collaborative educational processes in networks

This chapter introduces current and emerging trends for building collaboratively maintained knowledge structures that can be used flexibly for information retrieval and educational purposes. A promising framework has been wiki technology supporting open access and open source solutions to be implemented. It seems that many knowledge processing tasks can be fruitfully distributed to human actors who can then in self-guided manner produce impressive collective solutions to knowledge management and knowledge maturing. There is a need to develop computational methods that can exploit networks of knowledge and to identify pedagogically rewarding paths to be explored by learners.

3.1. Collaborative sharing of knowledge

It has been long recognized that learning is a highly *individual process* that is influenced by *prior knowledge* of the learner and the context of learning. There is a need for automated methods that can assist individual learners. Despite of benefits getting teaching provided by a human tutor, it is often a question of costs and distribution of resources that suggests that parallel *computer-assisted supportive methods* are needed for learners (Anderson & Jackson 2000).

Especially in *special education* the challenged learners have a strong need for supportive methods and even relatively simple new innovative tools exploiting computer technology can offer significant help (Hasselbring & Glaser 2000). For example to support knowledge acquisition in specific vocabulary learning tasks for visually impaired it has been noted how important it is to provide a tailored auditory vocabulary and spelling trainer (Stein et al. 2011). Another approach is to build systems trying to address more general knowledge acquisition tasks even though compromising somewhat the details and possibly to build it as a mash-up consisting of low-cost generic components (Lahti & Kurhila 2007). Computer-assisted learning can also offer valuable ways to enhance open and distance learning in developing countries (Gulati 2008).

In a meta-analysis Johnson et al. (2000) listed ten *cooperative learning methods* that have received a lot of attention in research including Learning Together, Academic Controversy, Student-Team-Achievement-Divisions, Teams-Games-Tournaments, Group Investigation, Jigsaw, Teams-Assisted-Individualization, Cooperative Integrated Reading and Composition, Cooperative Learning Structures, and Complex Instruction.

They found 164 studies that investigated eight of these cooperative learning methods, suitable studies were not found concerning the two last methods. When these eight cooperative methods were compared with either competitive or individualistic learning the greatest effect on achievement was gained with a Learning Together method which is based on setting a goal for group, sharing opinions and materials, dividing labour and reward.

Illich (1971) suggested designing learning webs to spread equal opportunity for learning and teaching, and that already 3-4 distinct channels of learning exchanges could provide all resources for learning and enabling to cover different aspects concerning things, models, peers and elders. For developing computer-supported collaborative learning at work Fischer (2013) lists some influential perspectives including distributed cognition, problem framing and solving, domain-oriented programmable design environments and communities of interest, as well as approaches collaborative knowledge construction including meta-design, cultures of participation and social creativity.

There have been many initiatives for computer-assisted learning methods introduced in the past and one key challenge has been high *development costs* to build a system that assists learning in a pedagogically meaningful non-trivial way, and typically it has been challenging to develop adaptive systems that can offer varied inspiring perspectives to the learning topic (Dagger et al. 2005). Fischer (2000) argues that educational reform has suffered from a tendency to use information technologies to mechanize old practices so that technologies have been primarily add-ons to old practices.

Development of intelligent tutoring systems has often required making laborious *manually tailored design* with careful effort of human experts to address a specific learning topic and it has been difficult to convert an existing system to manage a different learning topic, and thus self-improving intelligent tutoring systems have been suggested (Soh & Blank 2008). When using an intelligent tutoring system it can provide to the learner somewhat the same educational knowledge every time with about the same formulation due to common characteristics that the system controls the dialogue and offers limited possibility to diverse task-driven and on demand learning (Fischer 2000).

Fischer (2000) argues that to support life-long learning with suitable system one of the biggest challenges is to enable users to contribute to co-development of the system. Fischer mentions that when a system is designed, the system developers make decisions concerning users, situational contexts and task that rely on predictions about future use of the system, and when the system is actually used by users, the system can use these contextual factors to offer analysis and critique concerning the artifacts made by users. Fischer argues that there is a challenge to develop new innovative systems which enable the contextual factors to be specified by the users themselves and thus enable that a user can both learn from and contribute to a computational environment.

In development of adaptive educational systems it has been a challenge to introduce new knowledge to a learner gradually so that the learner's prior knowledge and needs have been taken into account fruitfully *preserving logic and continuity* and providing an

optimal increase in the level of complexity. It has been argued ((Thalman 2014) referring to (Akbulut & Cardak 2012)) that that continuum of adaptation needs of adaptive systems and how to match them to suitable learning materials has gained limited attention in research and main focus has been on learning styles rather than other factors. Besides providing adaptively suitable new information to learner it has been challenging to provide adaptively *personal choices* for the learner and for example exercises have often remained relatively monotonic and alternative ways to approach the same topic has not been often highlighted easily. Liao et al. (2012) argue that in research of game-based learning many empirical studies have focused on learning outcomes rather than learning process.

Based on survey of authors of 158 adaptive systems (Thalman 2014) concerning usefulness and effort of adaptation criteria required in creation of adaptive contents, it was found that in respect to usefulness five highest-ranking criteria were learning style, knowledge structure, previous knowledge, content preference and user status, and in respect to effort five highest-ranking criteria were learning style, user history, previous knowledge, content preference and language.

Zliobaite et al. (2012) argue that complex adaptive systems have remained as supporters of human decision making and not making actual decisions on behalf of them since people are not willing to give control to a machine and this situation becomes further challenged when dealing with streaming data instead of data stored in databases. In respect to student interacting with intelligent tutoring systems and self-regulated learning, Bouchet et al. (2013) argue that while there is an excessive amount of research of student models, most of it has not emphasized complex cognitive, metacognitive, motivational and emotional processes with non-linear hypermedia learning materials.

Bargel et al. (2012) argue that most of e-learning courses are still provided in a linear form, thus being based on online book that is supplemented by interactive elements of media and exercises, and it is sufficient to represent those courses by some type of hierarchical table of contents, but for adaptive e-learning systems enabling to recommend individual learning paths to the users there is a need for more expressive representations of knowledge. Ghali (2010) argues that the usage of adaptive and personalized e-learning systems appears to be low and interoperability between adaptive systems and learning management systems seems to be missing and collaborative and social features are limited. Adaptive systems remain challenged when aiming to offer easy, intuitive *recommendations* for the learner how to proceed pedagogically in her personal learning process or to offer methods for *collaboration* that efficiently and fruitfully combine complementing resources of individual collaborators.

A review of 143 research articles in 2007–2009 concerning Web 2.0 technologies that are supposed to offer a user-centric environment that is social, personalized, interactive and participatory showed that five most commonly discussed technologies include blogs, wikis, podcasts, social networks and virtual environments (Liu et al. 2012). A promising largely adopted relatively recently developed scheme for combining individual resources in collaborative knowledge construction process are *wikis* that are web environments enabling free asynchronous editing of shared knowledge in a web

site with a constant access to full edit history thus enabling to analyze the cumulative growth of information and reverting to previous versions of work in progress.

Beside active adoption of wikis, there have been various alternative proposals how to support collaborative work with computational methods. One example of interesting approaches is open-source tool Geogebra that has been developed for collectively building and sharing *visualizations* of mathematical ideas (Hohenwarter & Jones 2007). Kittur et al. (2011) have proposed a framework for accomplishing collaboratively distributed complex tasks using so called *micro-task markets*. With this approach collaboratively written articles were rated more highly and had lower variability than individual written articles and were rated having similar quality as simple articles of the Wikipedia. Based on hierarchical cluster structure of network, Yasui et al. (2009) have proposed a method for identifying *key persons* and *key terms* of a discussion in online collaborative environments by mutually reinforcing relationship between persons and terms.

3.2. Computational processes of collaborative knowledge

Various theoretical frameworks have been introduced trying to increase understanding about collaborative processes and to develop supportive methods for organizing and coordinating collaboration. *Knowledge management* can be considered as activities of planning, organizing, motivating and controlling in organization concerning people processes and systems that aim to improve and use effectively knowledge-related resources (King 2009). Knowledge management typically focuses on processes such as creation, acquisition, refinement, storage, transfer, sharing and utilization of knowledge, to support for example innovation, individual and collective learning and collaborative decision making so that one of its goals is organizational learning (King 2009). Related to knowledge management, we think that a promising direction for developing methods for computer-assisted learning is *human-based computation* which can be interpreted as computational techniques in which operations performed by computer are augmented with human resources (Wightman 2010). Wightman (2010) categorized systems that crowdsource human-based computation into four classes based on two dimensions which were the type of motivation the user had for completing the task (*direct or indirect motivation*) and whether completion of the task was competitive (*competitive or non-competitive tasks*). He positioned Wikipedia online encyclopedia into the class of non-competitive direct motivation tasks.

For collaborative and creative work there are diverse sources of *motivation* giving the driving force to proceed toward new solutions. The basis of motivation can be difficult to identify but a person's direct motivation for choosing and contributing to a specific work can be seen to originate from some kind of love or passion leading to a voluntary devotion. On the other hand, a person's indirect motivation for working can be seen to originate from getting some benefits or compensation from contribution, for example in the form of economical wealth and thus a salary can help to get people to participate in a work but it cannot guarantee the quality of contributions especially when

the quality is difficult to measure like in creative work. Anyway, the need to accomplish tasks exceeding the capacity of an individual and requiring diverse resources has led to formation of *communities* that enable individuals to complement each other's skills and knowledge and offer compensation for that.

Computational solutions have been developed to support *creative problem solving* relying on methods that try to enhance free thinking and associations and developing ideas further with specific guided processes. Vidal (2006) argues that three most used tools to support creative problem solving process are brainstorming that generates unconventional ideas with low criticism, mind mapping that visualizes structure of related ideas and SWOT analysis that evaluates strategies based on strengths, weaknesses, opportunities and threats. Some methods aim to be very unconstrained and keep criticism at low level like *brainstorming* relying on collective ideation that is progressively iterated to agreed solutions. When comparing nine different procedures for collaborative idea generation, it was found that the groups supplied with a facilitator produces several times more unique ideas than groups without a facilitator (Isaksen & Gaulin 2005). In groups having a facilitator, the highest number of unique ideas was produced by brainwriting method in which ideas written on paper were exchanged and also facilitator participated in writing. In groups without a facilitator, the group which was asked to follow brainstorming guidelines but work independently produced the highest number of unique ideas, followed next by a group instructed to engage in free discussion and then by a group performing brainstorming as a group. One computational approach to creative problem solving is offered by so called *expert systems* containing a broad collection of *axioms* and *heuristics* often manually coded to the system that can be used to build answers (Jonassen 2004, 688-699).

There have also been efforts to analyze and identify general, possibly universal, patterns of evolution, innovation and creativity that could be modeled and replicated in future work (Sabelli 2008). For example after identifying key features and principles of an *innovation* they could be generalized to generate other resembling innovations. One early and still influential work in this field is problem solving methodology called TRIZ (abbreviated from Russian term "teoriya resheniya izobretatelskikh zadatch" called in English as the theory of inventive problem solving) that is derived from the study of patterns of invention in the global patent literature and that has emphasized algorithmic approach to the invention of new systems (Nix et al. 2011). When evaluating four possible predictors to predict *problem-solving efficacy* in collaborative group discussions, Voiklis et al. (2006) considered four features: convergence value representing group's ability to approach solution, frequency of convergent interactions, relative frequency of convergent interactions, and difference between the number of convergent and divergent interactions. They found out that only the convergence value managed to recapitulate enough ontological and causal history to predict significantly problem-solving efficacy.

In complex problems, *genetic algorithms* and related *evolutionary computation* have been used to mimic the nature's evolutionary process to find solutions (Eiben & Schoenauer 2002). Solutions are generated with a methodology analogous to genetic engineering so that data is transformed through phases of recombination and mutation,

and a natural selection process is carried out with some kind of fitness function (Eiben & Schoenauer 2002). In *interactive genetic algorithms* the fitness function is replaced with interactive evaluations carried out by human users (Banerjee et al. 2008). In an early important work, a computer program asked a single human user to serve as a fitness function of an evolutionary algorithm (Dawkins 1986). Term *human-based genetic algorithms* has been used to refer to algorithms engaging a great amount of human participation so that phases of recombination and mutation are carried out through human innovation and natural selection through selection done by human decisions (Kosorukoff 2001). Takagi (2012) argues that since in *interactive evolutionary computation* human evaluations are used to optimize the target system it is possible then to analyze the target system to understand the human's evaluation metrics or mechanisms, like in reverse engineering.

Swarm intelligence is a domain of artificial intelligence composed of agents following relatively simple rules forming together without centralized co-ordination entities in which collective intelligent behavior emerges (Chu et al. 2011). Analogous to a gene as a molecular unit of heredity, Dawkins (1976) introduced a term *meme* to represent a basic unit of cultural evolution. *Memetic algorithms* introduced by Moscato (1989) refer to methods combining genetic algorithms to individual learning methods that can do local refinements and thus aiming to mimic cultural evolution. A range of *adaptive memetic algorithms*, belonging to *hybrid evolutionary algorithms*, have been developed with an emphasis on the choice of local search methods or memes which has shown to have a significant effect on the performance of problem searches (Ong et al. 2006). Malone et al. (2010) suggest defining so called *genes of collective intelligence* that can be used to classify collaborative activities based of four factors: what, who, why and how.

3.3. Computational organization of collective knowledge

Surowiecki (2004) presented arguments supporting existence of *wisdom of crowds* giving essential criteria for its emergence that are diversity of opinions, independence, decentralization and aggregation. To enhance innovation, Johnson (Johnson 2010) encourages to position creative work into collective networking environments that enable to identify unexplored adjacent possibilities. Hendler and Golbeck (2008) emphasize the need for combining two different networking spaces that originate in the social link structures of the social web applications and the semantic link structures of semantic web applications.

Bush and Mott (2009) argue that truly open, modular, and interoperable *learning ecosystems* are needed providing learner-centric content that can be reused, revised, remixed, and redistributed easily with tools and content that are seamlessly plug-and-playable supporting agreed technological, usability and accessibility standards. Tapscott and Williams (2010) suggest that the modern society is currently experiencing a transition to the age of *networked intelligence* that can revolutionize collaborative management and organizational life. They argue that this new era is largely influenced

by solving problems with mass collaboration of individual actors that is referred to as *wikinomics*.

Term *open access* is typically used to refer to a practice of providing free access to information sources, such as publications, and this freely accessible information can be called as *open content* or *open knowledge* (Atkins et al. 2007). Term *open source* has been largely used to refer to freely distributed and shared source code of computer programs but nowadays it can in broader context be used to refer to methodology of work that produces material and services that are provided publicly so that they can be used freely by anyone (Atkins et al. 2007). Having such web content available that supports free use of and free access can be seen as a valuable way to increase equal opportunities for learning and overall sustainable development of society. Collectively produced work and generation of content with it has been called *crowdsourcing* when emphasizing an organization's outsourcing of some work to loosely defined group of voluntary people often coordinated by the organization outsourcing the work whereas work of an open source movement is often coordinated by the members of collaborating community themselves (Atkins et al. 2007).

When individuals retrieve information from Internet it largely consists of web browsing by using *search engines* and traversing hyperlinks connecting web pages.¹⁰ A popular form of collaboratively collecting and sharing knowledge in web environment is *social bookmarking* usually meaning personal *annotation* of preferred and recommendable web sites with a set of keywords called tags, that are often category names, in a process called *tagging* (Noll & Meinel 2007). In contrast with file sharing, social bookmarking does not deliver actual content but instead only a reference to it. Categorization can be based either on predefined fixed set of tags or support free creation of new tags by users as needed offering wider diversity and flexibility but introducing challenges of how to guarantee consistent systematic naming that manages also synonyms and otherwise conflicting naming strategies.

Besides providing just single link recommendations, social bookmarking offers a possibility to analyze link structures on broader scale. For example, social bookmarking enables to identify groups of related web sites linked together and agglomerate and cumulate condensed essential parts of networks describing knowledge (Noll & Meinel 2007). By analyzing *hierarchies* and *clusters* of these networks it is possible to generate categorization and chaining of pieces of knowledge that can be useful for individuals searching for information (Halpin et al. 2007). To carry out this kind of analysis, there is a need for developing processes that enable selection of most promising pieces of knowledge among alternatives and that can incorporate ranking and competition.

There is also a need for developing methods for smooth joining, reordering and enhancing pieces of knowledge to form *logical entities* of knowledge with continuity

¹⁰ Efforts to systematically index, manage and control information available online are challenging. Even large knowledge entities, such as complete educational book series, videos and exercises, can be technically easily exchanged among learners and educators over the Internet by email or through file transfer protocols, file sharing web sites and peer to peer networks, but unfortunately due to complex *copyright issues* and lack of suitable online retailers many useful knowledge resources cannot be currently legally accessed online. Thus there is a need to develop legally flexible ways to distribute and redistribute educational material.

that can be shown to the individual searching for information (Corby et al. 2012). To enable this can require adaptation of pieces of knowledge depending on the context and based on the characteristics of the individual. For example, a currently popular search engine Google (<http://www.google.com>) claims that the original Pagerank method that it has used to rank a web page relies on the number and authority of arriving links to this web page and we think that this method can be seen somewhat analogous to social bookmarking (Brin & Page 1998).

Organizing knowledge to meaningful constellations in a collective process of a group of individuals is carried out by parallel individual human neural systems. Each individual neural system typically tries to do its own share of the collaborative work thus paying attention to participating in meaningful coordination and complementation of concurrent efforts of others and aiming to maintain a holistic understanding about the knowledge management and its aims. It has been suggested that for an individual becoming exposed to ideas of collaborators can stimulate concepts in her long-term memory which are connected by means of a semantic network and this stimulation can happen due to external cues activating ideas that are otherwise weakly accessible for the individual thus possibly leading to an associational chain of ideas (Dugosh & Paulus 2005). It has been also suggested that shared externalizations called as boundary objects are essential in collaborative knowledge processing to enable grounding shared knowledge and to support its evolution and refinement through interaction (Fischer et al. 2005). We think that it is possible that the knowledge management processes of collaborative work have some similar fundamental properties with the information processes of reasoning and creativity that are manifested in each individual neural system. We think that some motivation for this suggested correspondence can be based on general characteristics of network architectures called as *small-world networks* that seem to manage to represent quite well knowledge processing on various levels of abstraction ranging from structural and functional properties of human brain networks (Wang et al. 2010) to social networks of people (Uzzi et al. 2007), wikis (Mehler 2006) and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009).

We think that development of new computational methods relying on network representation of knowledge can have an important role in increasing understanding about how collaborative knowledge management process and individual information processing in neural system are related. In this development work we consider that the Wikipedia offers a unique resource of collectively cumulated knowledge and we think that valuable features that can contribute to educational potential of the Wikipedia can originate from the notion that the Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)). According to Bullmore and Sporns (2009), some studies indicate scale-free properties in functional brain networks ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008)) while some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Previous research has gathered collections of *associative pairs of concepts* including The University of South Florida Free Association Norms (Nelson et al. 2004) and Edinburgh Associative Thesaurus (Kiss et al. 1973). Analysis of Olney et al. (2012)

about cognitive-linguistic environment of the Wikipedia on three levels (including word-word, word-concept and concept-concept) found that the Wikipedia reflects the aspects of meaning that drive semantic associations concerning structure of language, organization of concepts/categories and linkage between them. Other research has considered semantic relations and associative relations of concepts to be related (McRae et al. 2011) and not to be related (Maki & Buchanan 2008). Olney et al. (2012) found that semantic similarity metric Wikipedia Link Measure (WLM) defined by Milne and Witten (Milne & Witten 2008a) had some correspondence with word association norms (WAN) of The University of South Florida Free Association Norms (Nelson et al. 2004) so that the median rank of the first five responses (having ranks in range 1–5) predicted by WLM in respect to word association given by humans in WAN was 6 and the proportion of the first responses predicted by WLM that match the first word association given by humans in WAN was 0.15. When considering individual triples containing stimulus word, response word and forward associative strength Olney et al. (2012) found that Pearson correlation between WLM and WAN was 0.20.

Lévy walks that are random walks having power law distribution for path lengths have been suggested to explain paths of animals searching for food with relatively optimal strategies ((Humphries et al. 2010); (Raichlen et al. 2014)). It has been identified that inter-retrieval intervals for both paths of animals searching for food and for human memory category recall resemble Lévy walks with power law having exponent alpha of about 2 ((Thompson et al. 2013) referring to ((Rhodes & Turkey 2007); (Sims et al. 2008))). Thompson et al. (2013) asked 19 students to recall concepts belonging to category of animals and contrasted them with a semantic network model based on a set of 5701 Wikipedia pages about animals thus finding that semantic memory processes can be usefully modelled as searches over scale-free networks and it was shown that inter-retrieval interval was progressively greater as minimum path length increased between nodes of semantic network to be recalled.

During a period of six weeks in 32-54 sessions Morais et al. (2013) had six students to grow individual *associative networks* with a snowball sampling paradigm each reaching 1358-9429 nodes and 3729-27124 directed links showing to have a small-world structure with average shortest paths between any two nodes being in the range of 5.65-7.05 links. Associative networks aggregated across responses of many people appear to have small-world network structure ((Morais et al. 2013) referring to ((De Deyne & Storms 2008); (Steyvers & Tenenbaum 2005))). Associative networks aggregated across responses of many people have been suggested to be have a scale-free structure ((De Deyne & Storms 2008); (Steyvers & Tenenbaum 2005)) but supplied with a reanalysis Morais et al. (2013) claim that they do not have a scale-free structure although having degree distributions similar with individual associative networks. When compared to individual associative networks, associative networks aggregated across responses of many people have higher average degree, larger connected components and shorter distances (Morais et al. 2013).

Earlier research trying to mimic the natural process of human neural systems with computational methods has relied on for example *artificial neural networks* and *machine learning techniques* (Akrimi et al. 2013). Important models of probability

theory used for creating computational representations about real world decision-making processes include *Markov models* and *Bayesian models* (Buntine 1994). Our research aiming to develop network based methodology for computer-assisted learning is inspired by the *spreading activation theory* of memory (Anderson 1983) that is a cognitive model suggesting that information is encoded in a network of interconnected cognitive units which have an ability to spread activation to related units to form activation patterns that represent specific conscious experiences. Based on meta-analysis considering 135 tasks it has been suggested that each brain area is redeployed to support other cognitive functions and more recent functions of cognition utilize increasingly scattered brain areas (Anderson 2007). Dix et al. (2010) proposed methods using spreading activation to link external knowledge repositories to personal ontologies based on activation of entities already held in memory and experimentally showed that working set of highly activated entities is typically small.

3.4. Personalized guidance for the learners

Intelligent tutoring systems or *intelligent tutors* are pieces of educational software created to support education with computational models about learning process (Jonassen 2004, 667). Typically they are student-centered rather than teacher-centered and have dynamic models trying to represent essential educational knowledge the student should learn, how the student can reason and how new knowledge is filtered and integrated to the student's existing cognitive structure and reshapes this structure (Woolf 2009). Intelligent tutors can take various forms depending on the features and representations that need to be addressed in the educational setting. Efforts of building intelligent tutoring systems has been supported by already an early experimental finding that an average student receiving individual instruction by a tutor outperformed 98 percent of the students receiving instruction in a conventional classroom setting (Bloom 1984).

There is a trend that new terminology is actively introduced to differentiate the consecutive development stages of computer systems and methodology although differences are not often clear and thus terminology is overlapping. Even if intelligent tutoring systems can seem to be a somewhat old-fashioned term we consider it as a simple descriptive overall naming that we have liked to use to refer to the methods we have developed in our research. However, it should be noted that intelligent tutoring systems in general and in our work especially can contain and mix many features that make them closely related to domains often referred to as instructional design, microworlds, cognitive tools and guided discovery learning. In our work, the intelligent tutoring system aims to offer an intelligent learning environment relying on computer-supported collaborative learning and adaptive hypertext.

Intelligent tutoring systems typically consist of few complementing models to help processing educational scenario with manageable modules and hierarchy. It has been suggested that intelligent tutoring systems should contain a problem-solving/expertise module, a student-modeling module and a tutoring module (Jonassen 2004, 667). In

adaptive learning systems in general a relatively common practice is to separate three perspectives: domain model, student model and pedagogical model ((Kump 2010) referring to (Shute & Towle 2003)). *Domain model* aims to represent the structure of the learning domain with educational content, *student model* aims to represent information about the learner's current knowledge (or knowledge level) about learning domain, and *pedagogical model* aims to represent knowledge about how to tailor presentation of educational content according to student model ((Kump 2010) referring to (Shute & Towle 2003)). A traditional approach is to create domain model according to knowledge of a human expert in this field and to use a subset of this domain model as a student model which can be referred to as an overlay student model (Jeremic et al. 2012). Since domain model has a crucial role as a basis for interference and predictions concerning the learner's interaction with the system there is a need to develop systematic processes that can guarantee quality of domain model. Kump (2010) suggests methods and techniques for validation of different features of a domain model in an adaptive work-integrated learning system that should enable formative evaluation leading to concrete implications of revising the model.

It has been long recognized that gaining fluent skills to read and to express oneself with language are motivated by rich communication (MacWhinney 1999). This implies that varied *collaborative environments* should be introduced to everyday activities of a learner. Besides face-to-face communication also web-based collaborative platforms can provide additional support for challenged learners (Chou & Liu 2005). Since interpreting and understanding natural language reliably still mainly remains as an unsolvable computational problem, in current research it seems feasible to focus on developing support systems that enhance learning processes on relatively general level instead of trying to mimic the evolution of learner's knowledge with vague models about for example consciousness.

It has been argued that computer-based learning materials seem to force learners to single-mode pedagogy with linear or sequential design although they should promote nonlinear, interactive practices with context-sensitive and active learning elements accommodating diverse learning levels and styles ((Robberecht 2007) referring to ((Lee et al. 2004); (Swaak et al. 2004); (Phelps 2003); (Chen & Macredie 2002))), and these previous results motivate us in our research to try to develop methods that activate learner's own motivation, inspiration and problem solving skills.

Successful learning requires systematic introduction of new concepts to the learner so that they can be carefully associated with previous knowledge (Marzano 2004). There is a need for frameworks to support *personalized adoption* of new knowledge that matures along the learners in a synthesizing way (Collins & Halverson 2010) and *collaborative construction* of knowledge resources (Manouselis et al. 2010) supplied with sufficiently converging *free exploration* and recommending connections that are currently most potential for the learner's needs. To provide guidance for a learner with an adaptive intelligent tutoring system typically requires parametrization of learning process that relies on some theory like item response theory approximating learner's answers with a probabilistic function (Mohamed et al. 2012).

Among many competing learning theories (as discussed in Subchapter 1.4) *constructivism* has remained widely supported. In brief, it states that humans generate knowledge and meaning from their experiences. Holmes et al. (2001) suggested an expanded definition of social constructivism that could fully address the synergy between advances in information technology and virtual environments. One general challenge comes from the long-lasting debate if semantic structures of natural language are independent of syntactic structures or not (Peregrin 2010). *Transferable learning* that enables applying previously acquired training successfully for novel future events can be achieved through the learner being exposed to the learning material in a variety of contexts (Schmidt & Bjork 1992). Designing learning activities can exploit the notion that people typically predict upcoming words in fluent discourse (Van Berkum et al. 2005). There is evidence that concept-oriented reading instruction increases reading comprehension and engagement (Guthrie et al. 2004).

Serrano et al. (2009) argued that some key regularities of written text concerning burstiness of words, topicality and their relationship can be modelled with two simple algorithmic techniques that are *frequency ranking* with dynamic reordering and *memory effect* connecting word frequencies across different documents. They suggest that their model enables to relate two key mechanisms that have been assumed to affect how humans process the lexicon: rank frequency and context diversity. They propose using their model to study coevolution of content and citation structure for example in the Wikipedia. In a resembling fashion, in our research we believe that learning can be successfully supported with a similar approach and thus have developed methods that use rank frequency and context diversity of the Wikipedia enabling a learner to process lexicon to a pedagogically rewarding structure.

Creative learning strategies are needed to boost creative thinking by helping the learner to get inspiration, to achieve a new perspective and to focus her attention to things that support creation of a new idea (Hilliges et al. 2007). As a computational approach for semantics Gärdenfors (2004) has suggested a model of *conceptual spaces* for representing the meanings of different kinds of linguistic expressions. In addition, Fauconnier and Turner (2008) have argued about the human talent to create *great arrays of conceptual variety* that can be compressed into manageable regularities and connected to large mappings. Also, Gero's *Function-Behaviour-Structure model* of conceptual design (Gero 1990) has offered methodology to manage with creative process.

3.5. Representations of collaborative knowledge

In computer-assisted education, a strong trend is to develop *learning objects* that are modular resources designed to explain learning objectives (Koller et al. 2006) and *intelligent tutoring systems* that provide automated guidance like an experienced human tutor (Corbett et al. 1997). For a pedagogically motivated and tailored learning experience, *visualizations* in many forms can support knowledge management (Eppler & Burkard 2006). Various compact notation techniques, such as diagrams and

flowcharts, are used to compress information to more manageable units and to highlight essential relations. However, punctuality becomes easily sacrificed and it is challenging to find a good balance with compactness and detailedness in visualization. We think that new domain-independent adaptive methods are needed to manage knowledge with a compact notation that has an optimal expressiveness. Interpreting compact notations is often easiest for people having a shared history although creative work benefits from varied backgrounds. We think that concept maps are an illustrative and adaptive notation technique that should be increasingly exploited to support collaborative creative work.

Despite the broad usage of *concept mapping*, all the potential of this compact notation has not yet been unleashed (Bonastre & Pina 2005). Concept maps are graphical visualizations that typically consist of nodes labeled with concepts that are connected with directed labeled arcs depicting the relationships between concepts. Concept maps have resembling variations, including mind maps and semantic maps, having diverse alternative definitions and having been used for long time with positive reception in education ((Johnson et al. 1986); (Novak & Gowin 1984); (Al-Kunified & Wandersee 1990)). Concept maps have been suggested to suit better for reviewing activities in the classroom than for individual vocabulary learning strategies (Nielsen 2002) but on the other hand also to support vocabulary instruction for students with learning difficulties (Baker et al. 1992). Stahl and Vancil (1986) found out that to use semantic mapping effectively in vocabulary instruction it needs to be supplied with a discussion and that instruction relying just on discussion can offer similarly effective results. Concept maps have been also promoted for active use in visualization of scientific research (Wheeldon & Ahlberg 2011). Stanton et al. (1992) suggest that navigational aids for browsing hypertext should be designed so that they support development of the learner's own cognitive map about the topic and enable the learner to direct control representation of the content.

By building and modifying a visual concept map each learner can express and reflect her own *mental conceptual structures*: what are the meanings for each concepts and how they are related. In addition, the process of building a concept map allows to explore alternative conceptual structures and to compare them flexibly in a constructive manner. Especially when collaborating using a shared concept map, the learners can complement each other fruitfully by providing feedback and further ideas. Also automated evaluation of built concept maps (La Vecchia & Pedroni 2007) and solutions addressing special needs (Blenkhorn & Evans 1998) have been proposed.

According to a classical but criticized theory, *concepts* are structured mental representations that encode necessary and sufficient conditions for their application (Laurence & Margolis 1999). In computational natural language processing, the ambiguous *mappings* of words to concepts are often analyzed as *correlation patterns* in large text samples. Online knowledge resources have received increasing attention since they can be easily accessed and updated by anyone. In digital format related pieces of knowledge can be versatilely connected with *hyperlinks* thus forming networks. *Semantic features of networks* have been modelled from various perspectives including learning, graph-based representation and information flows ((Gladun et al. 2007);

(Baget et al. 2008); (Erétéo et al. 2009)). Based on statistical analysis and probabilistic methods, models have relied on lexicographical resources like WordNet (Fellbaum 1998), manual statements like in CYC project (Lenat 1995) and the contents of the Wikipedia (Krötzsch et al. 2007).

Anyway, it has remained challenging to automatically *extract semantic knowledge* from natural language documents. Computational language models have used for example n-grams and hidden Markov models, as well as various tagging and parsing techniques (Bird et al. 2009). A common assumption has been that co-occurrence of certain words in a small observation window and in a specific order indicates their semantic relatedness and similarity. However, indexing word distributions from large corpuses typically results in sparse high-dimensional vector spaces that are often inefficient in making searches and comparing distances, despite of advancement in dimensionality reduction techniques. *Categorization of documents* often relies on weighting and ranking matching documents. Two basic trends are *statistical indexing* and *intelligent indexing*. The former approach has suffered from an unrealistic assumption of independence of the index terms. This has encouraged the latter approach which consists of conceptual and semantic indexing (Wang & Brookes 2004).

Text classification has strongly relied on so called “bag of words” approach combined with for example k-nearest neighbour algorithms, support vector machines and artificial neural networks. Thus, usually only words explicitly mentioned in the text fragments have been considered, assuming the vocabulary to be consistent everywhere. Knowledge resources used for creating classification models have often had a limited coverage and challenges to be updated. Also the agility to both generalize and differentiate has been limited. *Tf-idf weight* (i.e. term frequency – inverse document frequency weight) is a general statistical measure for evaluating how important a word is to an article in a collection of articles (Salton & Buckley 1988). It reaches high values if the word appears frequently in the article but rarely in the whole collection. Network models enable many linking schemes to express parallel semantic relations between textual items on various levels of abstraction and to tolerate possibly overlapping and fuzzy categorization. In article networks, *Pagerank* is a popular measure used to denote importance of an article based on the amount of arriving links and their corresponding value and an old interpretation is that the Pagerank value of an article can express the chance that a random surfer will arrive to this article through a link (Page et al. 1999). Both tf-idf and Pagerank measures have a limitation that to work well they initially need to perform a computationally heavy indexing through the collection of articles.

One computational approach often referenced as “*semantic web*” relies on building a common model of knowledge, so called *ontology*, by defining simple relation statements that link concepts. There are challenges to ensure coherent categorization when combining statements from varied human contributors and to deal with ownership and neutral management policies of collaboratively built knowledge resources, such as Open Directory Project (Hammond et al. 2005). Maintaining a constant update rate can be difficult for many initiatives. Besides defining relation statements manually, ontologies can be extracted from web content labelled with community generated tags (Nauman et al. 2008). This metadata actively produced by social bookmarking creates

collections of *folksonomies* (Lachica & Karabeg 2008). However, loose coordination and non-explicit criterion induce ambiguity reflecting varied individual preference and experience. Abuse for search engine optimization and anonymity of collaborators can also reduce reliability of tagging.

To bring structure to the meaningful content of web pages, so called semantic web approach aims to introduce ontologies as a formal representation for concepts within a domain and the relationships between them (Berners-Lee et al. 2001). However, many traditional ontology projects have received criticism about being too closed, formal and hard to update (Simperl & Tempich 2006). Zouaq and Nkambou (2009) proposed a method to automatically generate a domain ontology from plain text documents and use this ontology as the domain model in computer-based education. They suggested evaluating the generated domain ontology with three dimensions: structural, semantic, and comparative.

To manage knowledge structures, ontologies try to offer formal explicit specification of a shared conceptualization. Knowledge structures can be intuitively visualized with *concept maps* typically consisting of nodes labeled with concepts connected with labeled directed arcs depicting their relationship.

In adaptive hypermedia systems adaptation techniques have been categorized into adaptive presentation and adaptive navigation support so that adaptive navigation support further consist of direct guidance, adaptive link sorting, adaptive link hiding, adaptive link annotation, adaptive link generation and map adaptation ((Tsandilas 2007) referring to (Brusilovsky 1996)).

According to Chen (2002) it has been identified that the use of *linear and non-linear pathways* in hypermedia environment is affected by a cognitive style based on measure of *field dependence* versus *field independence* originating from experiments of Witkin and Asch (1948). Persons having cognitive style of field dependence are claimed to have more social orientation, seek external referents for knowledge, better learning human-related content and easily influenced by others' opinions and authorities, whereas persons having cognitive style of field independence are claimed to have more individualistic orientation, develop own internal referents for knowledge, better learning impersonal abstract content and not easily influenced by others' opinions and authorities ((Chen 2002) referring to (Witkin et al. 1977)).

When analyzing linear and non-linear navigation patterns of students it was found that in two first stages of three stages the field dependent students took more linear steps than the field independent students ((Chen 2002) referring to (Reed & Oughton 1997)). Also it was found that in learning strategies field independent students had a tendency to jump freely from a point to another with index tool whereas field dependent students had a tendency to follow a sequence from the start to the end ((Chen 2002) referring to (Liu & Reed 1995)). Furthermore field independent students performed better than field dependent students in exploratory learning in hypermedia learning program ((Chen 2002) referring to (Williams 2001)) and information searching tasks in hypermedia documents ((Chen 2002) referring to (Chang 1995)). In respect to learning achievement and learning time with computer-based instruction program, field independent students

performed better with non-linear presentation and field dependent students better with linear presentation ((Chen 2002) referring to (Yoon 1994)).

It has been suggested that hypermedia learning programs can help field independent learners by offering multiple routes, free choice and visual control ((Chen 2002) referring to (Reiff 1996)), and can help field dependent learners by offering guided routes, labelling the role of current position along path and separate directions to required information ((Chen 2002) referring to ((Chou & Lin 1997); (Polson & Lewis 1990); (Hedberg & McNamara 1989))). According to Chen (Chen 2002) adaptive hypermedia systems can offer four types of support for navigation, including direct guidance, links hiding, annotated links and link ordering, and that especially first three of them can address the needs of field dependent learner. We think that link ordering can be used to implement indirectly navigation support closely resembling approaches of annotated links and links hiding, and thus we think that also link ordering can be used to offer navigation support to field dependent learner. A brief overview of some aspects about how we aim to address field dependence versus field independence concerning educational exploration in the hyperlink network of the Wikipedia in respect to proposals we made in publications [P1]-[P9] are discussed in Subchapter 5.2.

3.6. Knowledge resources based on wiki technology

Wikis are collaboratively created and edited interlinked web sites with simplified markup language and full browsable edit history and Wikis have opened useful approach for asynchronous generation and editing of knowledge as well as a fascinating research domain concerning collaborative knowledge maturing process, inspired by the rise of the Wikipedia online encyclopedia. Creation of the first online wiki service, taking place in 1995, has been credited to Ward Cunningham who has been quoted describing wiki as “the simplest online database that could possibly work” (Leuf & Cunningham 2001). Etymologically wiki refers to a term meaning quick in Hawaiian languages. For clarification, a preferable spelling is wiki (with plural form wikis) although sometimes alternative spellings can be seen in literature and have been used also in our previous publications (such as considering this word as a proper noun Wiki and using plural forms wikies/Wikies). Collaboratively maintained web sites of wikis have been actively adopted as new educational environments with an assumption to support constructive learning process but however typical use of wikis may enhance merely student engagement, but not performance on assessment (Neumann & Hood 2009).

Cress and Kimmerle (2008) presented a theoretical framework describing how learning and knowledge building process can happen in the social system of wiki and the cognitive systems of the users. Based on empirical analysis of using the Wikipedia, Cress and Kimmerle suggest that individual learning can emerge due to *equilibration activities* caused by subjectively observed incongruities between the individual’s knowledge and the wiki’s information. It has been suggested that wiki environments work best with organizations who don’t have strict hierarchy and who can agree about

working guidelines and conflict resolution mechanisms, typically requiring that all aspects of controversial topics need to be covered (Todorov 2009). There has been an attempt to develop tools that support building and exploring semantic knowledge structures with wiki technology and that can offer shallow learning curve and expressiveness of natural language (Kuhn 2009).

Bauer (2007) showed that machine learning techniques can be successfully applied to classify semantic relations from the hyperlink structure of the Wikipedia and found that simple *lexical features* are suitable for detecting hypernym but significantly worse for hyponym, possibly due to hyponyms being often in lists that offer limited context to be extracted. Features generated from *categories* are usable but worse than lexical features. In addition, Bauer showed that the chosen vector representation introduced sparseness of feature representation but was still manageable for both support vector machines and decision trees. Support vector machines performed slightly better but decision trees achieved higher precision yet compromised with lower recall.

Our work relies on assumption that exploiting wiki based knowledge resources can be a promising way to build, explore and adopt knowledge. An important earlier work having resembling to our proposals is a hypothetical system called *Memex* suggested and introduced by Vannevar Bush (Bush 1945) (Vannevar Bush spells the name with lower case letters, i.e. memex). Memex was described as a device based on microfilm technology enabling an individual to store all her books, records and communications and this knowledge entity could be consulted fast and flexibly as a supplement to one's memory. So called associative trails could be created by an individual by chaining links across an arbitrary sequence of frames of knowledge supplied with personal comments and side trails. The idea of Memex has been said to have been directly influencing on the development of hypermedia and hypertext systems leading to the introduction of the World Wide Web. However, it seems that typical hyperlink architecture of the Web has relied on relatively mechanical hierarchy of indexing that is challenging for semantic exploration of knowledge and it has not been until emergence of wiki architectures and the Wikipedia when the Memex's idea of associational linking across pieces of knowledge has become easily available. One of the Vannevar Bush's inspiring predictions is that:

"Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified." (Bush 1945).

Thus for us it appears that Vannevar Bush has already long before online learning era suggested methodology for personalized exploring in knowledge structures relying on collectively built cumulative complementing pieces of knowledge.

Open access and *open source* movement has revolutionized availability and distribution of knowledge and one of the most promising and popular open access knowledge resources is the *Wikipedia* online encyclopedia (<http://www.wikipedia.org>). Supported by a non-profit Wikimedia Foundation (<http://wikimediafoundation.org/wiki/Home>), the Wikipedia is a multilingual project containing 286 language editions having altogether about 28.6 million articles that have

cumulatively reached about 1.65 billion edits as of August 2013 (List of Wikipedias 2013). According to Alexa Internet's web traffic reports the Wikipedia is about the seventh most popular web site globally, and a visitor spends daily approximately 4 minutes and 36 seconds on the site, there are about 3.71 pageviews per visitor and about 53 percent of visits contain one pageview only (Alexa Internet 2013).

Wikimedia Foundation maintains a diverse collection of encyclopedic projects related to the Wikipedia that partially share same resources and for example among different language editions there exist natural overlap about article topics and content. In August 2013, eight language editions (English, Dutch, German, Swedish, French, Italian, Spanish and Russian) contained over 1 million articles, 46 language editions over 100000 articles, 120 language editions over 10000 articles and 223 language editions over 1000 articles (List of Wikipedias 2013). Foundation of the Wikipedia has been credited to Jimmy Wales and Larry Sanger and formal launch happened on 15th of January 2001. In our Wikipedia related research started in 2008 we have decided to focus our analysis only on the biggest language version *English edition of the Wikipedia* (<http://en.wikipedia.org>) that has grown during our five years of research from about 2.1 million articles in January 2008 to about 4.3 million articles in June 2013 (Wikipedia statistics 2013).

The members of Wikimedia Foundation and active volunteers have formed an organizational structure for coordinating the development of the Wikipedia. New features have been introduced to the layout of the article pages of the Wikipedia along the years, also during the preparation of this dissertation. For example, there has been evolution in the functionality of the so called infoboxes and navboxes that are standardized visual components which have been increasingly added to article pages to represent some key facts and related hyperlinks in a compact form. Responding to many earlier suggestions about enhancing the ways to measure the quality of the Wikipedia's content, in September 2010 a new feature called Article Feedback tool was for the first time deployed in a collection of English Wikipedia articles, and its use was expanded to about 100 000 articles by May 2011 (http://www.mediawiki.org/wiki/Article_feedback). We would not be surprised if some pedagogically motivated features or visualization techniques related to ones we have suggested in our publications [P1]-[P8] would appear some day in the future to the layout of the Wikipedia, at least as alternative supplementary add-ons.

In close relationship with Wikimedia Foundation is a collaborative platform *Wikimedia Toolserver* (<http://toolserver.org>) operated by registered association "Wikimedia Deutschland e. V." which hosts and supports various software tools for contributors. Besides gathering and maintaining cumulative logs of data about the current state and historical evolution of the knowledge structure of the Wikipedia and patterns of retrieving articles by readers, community surrounding Wikimedia Foundation offers open solutions to analyze also emerging trends and information needs that are not yet satisfied. It is possible to retrieve listings about most wanted still currently missing articles (http://en.wikipedia.org/wiki/Wikipedia:Most_wanted_articles).

Based on planning among ordinary community members, a Strategy Task Force formed in February 2010 has formulated *development goals* for the Wikipedia for the next five years, including the following: increasing reach, improving content quality, increasing participation, stabilizing infrastructure and encouraging innovation (http://strategy.wikimedia.org/wiki/Strategic_Plan/Movement_Priorities). In September 2011 Wikimedia Foundation introduced a new educational application QRpedia which enables retrieving supplementing information from the Wikipedia for any encountered physical object that is supplied with a specific quick response barcode (QR code) tag that can be read by the camera of a smartphone (Wyatt 2011). This QRpedia application has been already adopted by some public institutions and it has been considered promising for example for galleries, libraries, archives and museums. In September 2012 Wikimedia Foundation announced that they make publicly available anonymous search log files for Wikipedia and its sister projects thus opening new opportunities for analyzing populational patterns and trends of search queries made to exploit encyclopedic knowledge (van Liere 2012).

Reliability of the Wikipedia's factual contents has been questioned but there have been verifications indicating the reliability to match traditional encyclopedias ((Giles 2005); (Chesney 2006)). The *coverage* when measured with the number of entries has already become much greater in the Wikipedia than any traditional encyclopedia and possibly any previously existing encyclopedia (for example English edition of the Wikipedia having 4.3 million articles in June 2013 whereas recent print editions of Encyclopaedia Britannica contained about 65000 articles (Berinstein 2006)). Also continuing relatively high rate of growing and updating is typically differentiating the Wikipedia from all other information sources of its kind. The number of articles in the English edition of Wikipedia (4.3 million articles in June 2013) has become higher than some estimates about an average human vocabulary (for example Nation and Waring (1997) suggest that a university graduate has a vocabulary of about 20000 word families). What is especially interesting is that the *full edit history* of Wikipedia articles can show how pieces of knowledge have been agglomerated and edited by collaborative authors gradually in a voluntary refinement process and linking and various categorizations have been established thus grouping and associating various terminological and thematic topics. Due to lucky discovery in 2010 of very early edit history data that was already thought to have been permanently lost from the early months in 2001 made it appear that full continuous edit history of whole Wikipedia so far has been successfully archived (Starling 2010).

It can be seen from evaluations carried out in 2007 and 2012 that during five years in between general attitude towards *educational use* of the Wikipedia has become increasingly accepted and despite earlier skepticism nowadays many schools and educational authorities have promoted various initiatives to exploit Wikipedia and its related projects to support learning ((Konieczny 2007); (Konieczny 2012)). Cosley (2006) offered theoretical and experimental indications showing that the strategy used also by the Wikipedia to publish all contributions instantly instead of a pre-review process accumulates value faster to community but after passing certain threshold of generated value the growth diminishes and it might be beneficial to switch to pre-review

policy. Despite the fact that the contents of the Wikipedia can be freely edited by anyone it has been found out that only a small portion of editors account for most of the work actually done and the value actually produced ((Panciera et al. 2009); (Nagaraj et al. 2009)). Li et al. (2012) report based on experiment with primary school students that using a wiki-based collaborative process writing pedagogy can support writing motivation as well as improve writing ability, computer skills and ability to collaborate.

3.7. Using the Wikipedia as a conceptual network supporting education

A leading wiki site, the Wikipedia online encyclopedia, provides an extensive coverage of factual knowledge from various domains of life and is actively used as a resource by students and educators. Despite of the concerns about inaccuracies, missing references and vandalism, the content has been shown to be relatively reliable and up to date (Chesney 2006). The content can be added and edited collaboratively by anyone but some parts are more protected to prevent vandalism and consistent rewriting. General usage patterns for various Wikipedia editions have been analyzed (Reinoso et al. 2009) showing a ratio of 620 reading operations per one saving operation for articles in the English edition.

We think that collaboratively built Wikipedia online encyclopedia has revolutionized gathering and sharing knowledge with the open access and open source movements. The maturing process of an individual to adopt knowledge can be paralleled with the development of knowledge of the population. The cultural evolution, creative experimentation and documentation have enabled gaining new understanding about principles of life and building lasting knowledge structures that can be passed to new generations. We think that the foundation of Wikipedia and its building process can be seen to demonstrate the building of an inventory of essential *human knowledge*. The decisions intuitively done by a diverse collective of contributors concerning what kind of pieces of knowledge should be added and edited in this knowledge entity, how to cross-link them and in which order these actions appear can be seen to represent an average mutual agreement about how the most valuable pieces of knowledge and their linking emerge and interact in human consciousness. Therefore we think that the learning processes of a human individual and adoption of conceptual knowledge by children along their early years can be paralleled with the mechanisms and patterns that can be identified in the gradually step by step advancing building stages of the Wikipedia.

We do not claim that the conceptual network of the Wikipedia is capable to mimicking the intellectual abilities of a human mind but anyway we suggest that it is reasonable to suppose that thinking and understanding performed in human mind largely deal with conceptual dependencies, relations and causalities that can be fruitfully compared and supported with *conceptual structures* emerging in the Wikipedia. We motivate our suggestion with findings that small-world topology has been identified structurally and functionally in human brain networks (Wang et al. 2010) as well as in

the Wikipedia (Ingawale et al. 2009), and that also scale-free properties have been possibly identified in functional brain networks ((Bullmore & Sporns 2009) referring to ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008); (Achard et al. 2006); (Bassett et al. 2006))) and surely identified in the Wikipedia ((Zesch & Gurevych 2007); (Masucci et al. 2011)). Addressing increasing interest in modeling evolution of small-world networks and scale-free networks Chen and Morris (2003) compared evolving visualizations of co-citation networks of scientific publications with two common link reduction algorithms, *minimum spanning trees* and *Pathfinder networks*, in respect to topological and dynamic properties. They concluded that in models of minimum spanning trees high-degree nodes dominate the structure but high-order shortest paths suffer from significant links becoming removed whereas in models of Pathfinder networks cohesiveness of some of the most pivotal paths can be maintained thus offering more predictable and interpretable growth animation.

Müller et al. (2008) describe various perspectives that can be used to analyze wiki networks including social perspective (collaboration network, discussion network and message exchange network), knowledge perspective (competence network), information perspective (wiki-link network, author-link network and category network) and temporal perspective (information-flow network and visiting-flow network). Since a young child typically has a limited vocabulary that becomes gradually expanded we think that the growth process of knowledge of a child can have similarities with the characteristics of the temporal dynamic growing process of the Wikipedia and the static link-structures captured from any timeframe of the evolution history of the Wikipedia. Of course the Wikipedia represents a collectively produced average of individual work and thus does not have characteristics of an individually built knowledge structure and cannot necessarily address ideally requirements for a specific individual or her individual knowledge building process. On the other hand, the average nature of the knowledge structure of Wikipedia guarantees that when used by any random individual to support her knowledge building process there should be relatively high probability that her requirements overlap with the knowledge structure of the Wikipedia.

To provide useful support for an individual learner, we suggest to offer collective and diverse support instead of just a single examples and to invest some effort to find most suitable collaborators. For example, if a learner is just randomly coupled with any single co-learner or teacher there is a risk that too different mindsets and background knowledge—or too similar ones—prevent a fertile learning to happen. In addition, the question of limited resources is one important motivator to rely rather on collective than single support for learning. It is economically impossible to enable a private personal teacher for every individual learner. When aiming to find new ways to facilitate learning with automation, we think that it is useful to have some kind of collectively generated *collection of resources*. Without this kind of initial collectively built resource it seems to be difficult to develop suitable computational models and methods for social activities that have been used in traditional teaching. It also seems to be very laborious to develop a reliable automated process that can generate unique learning material for each individual learner from the scratch just based on the information about the learner. Thus to maintain sufficient efficiency in automation we suggest instead that a common

collective resource that represents the needs of an average learner is used as a basis for generating learning material of each individual learner and it is tailored with sufficient modifications to address individual needs differing from average. We think that this approach to create automated support for learning that relies on collective basis also enables to make useful long-lasting modeling about learning processes, thus enabling comparative analysis about how the collective basis is tailored for each individual and enabling sustainable cumulative development of learning material.

In addition, it seems that somewhat *average nature* of various qualities seems to be the only type of knowledge structure a free collective process can easily produce. Thus even if a collective process can have hierarchical organizational features, we believe that its creative work cannot be kept well alive if controlled very strictly so it is important to enable and accept somewhat chaotic and average outcome resulting from collective work.

The collaboratively edited constantly growing Wikipedia online encyclopedia currently contains over 4.3 million articles in English (as of June 2013) in its biggest language edition (<http://en.wikipedia.org>). Each article defines a concept denoted by its title and the hyperlinks between articles define directed *conceptual relationships*. We think that enabling learners to explore hyperlink network of the Wikipedia pedagogically can provide sufficient coverage in core educational contents about many typical curriculum, especially in primary school and with challenged learners.

We suggest that there can exist parallel related processes of growing conceptual structures in both an individual human mind and a collectively built Wikipedia online encyclopedia. We do not claim that the *conceptual networks* in human mind and the hyperlink network of the Wikipedia are at all similar but anyway we want to emphasize that both structures have a somewhat limited number of individual concepts and they can be linked pair-wise with a somewhat limited number of links. Therefore even if there is a great difference in how the concepts in both collections are actually crosslinked, there are some shared general features relying on the aim to represent knowledge and understanding about principles of life with a limited set of cross-linked concepts. Motivated by this comparison, our work aims to open new perspectives to model human consciousness, thinking and planning with resources available from the Wikipedia. We think that learning processes can be possibly better understood and supported with the methodology that parallels conceptual structures of both human mind and the Wikipedia.

One promising domain to extract community generated tags for *ontology construction* is offered by the Wikipedia online encyclopedia. The Wikipedia provides an actively updated cross-linked network of articles and statements. For example article titles, article categories and hyperlink texts can be exploited as they were “tags” of a Wikipedia article (i.e. somewhat resembling tags used in social bookmarking). They indicate keywords or keyphrases describing a natural language concept represented by the corresponding article. It is computationally favourable that many of these tag-like features in Wikipedia articles obey hierarchically evolving abstraction and facilitate identification of the most essential semantic relations. For example, only a fraction of words in an article are hyperlinks and the hyperlinks in the beginning of an article

provide often definitive relations whereas later hyperlinks provide more illustrative and detailed relations. In addition, the hyperlink distribution in both basic and advanced articles usually inherently supports rising the abstraction level in reasonable steps when accessing hyperlinks. The presence of this layered abstraction in the hyperlink network of the Wikipedia is a critical feature that favourably supports building a true ontology. According to Strube and Ponzetto (2006), collaboratively created folksonomy extracted from the Wikipedia can be used in artificial intelligence and natural language processing applications with the same effect as hand-crafted taxonomies or ontologies. They suggest computing semantic relatedness of concepts by retrieving corresponding Wikipedia articles and measuring their textual contents and paths in the category taxonomy.

Building both learning objects and intelligent tutoring systems has typically been laborious and become cost-effective only in a highly specified domain. We wanted to find new ontology-related solutions. Unfortunately, among many defined *learning content models*, only a part of them supports standardized ontology-based content and metadata ((Verbert & Duval 2004); (Zouaq et al. 2007a)). Since manual generation of ontologies is slow and prone to errors, we considered automated or semi-automated methods as a necessity. We think that a community-driven approach, such as wiki environments including also the Wikipedia, can well support dynamic *collaboratively defined ontologies*. The Wikipedia does not have permanently fixed categorization of its content and the relations can sustain even radical changes to respond the changes in the average worldview. The content providers are asked to take care of updating the organization of the content as well. Since previous versions can be always reverted, it is safe to let the structure freely slowly converge towards a consensus while complementary contributions are gathered.

Despite uncertainties, the Wikipedia has been considered as a promising source for ontology construction ((Haase & Völker 2008); (Hu 2010)). Every Wikipedia article describes one concept denoted by the title of the article that has been considered having value for general public. Each hyperlink of this article literally shows a path to another related concept that has been collectively valued so much that a specific article has been written about it as well. Holloway et al. (2005/2007) suggest that they presented possibly the first *semantic map* of the English Wikipedia data.

We propose that browsing hyperlink structure of the Wikipedia can help learners in acquisition of new knowledge. In this sense, one earlier related work that is not based on the resources of the Wikipedia is a tool developed for expanding vocabulary of learners by collaboratively entering and reviewing unfamiliar words with an online database (Horst et al. 2005). Coursey et al. (2008) argued that a combination of *keyword extraction* techniques combining graph-theoretical algorithms and methods relying on knowledge extracted from the Wikipedia can be successfully used to identify candidate keywords in learning objects. They suggest using ranking algorithm over the Wikipedia connectivity graph to find relevant articles. Somewhat similarly, our method exploits the titles of hyperlink's target articles to identify promising concepts in the Wikipedia. We introduce ranking that enables these concepts to be explored in learning paths,

accompanied with compact relation statements parsed from the sentences surrounding each hyperlink.

The knowledge structure of the Wikipedia reflects the way humans as a community organize and relate things and concepts. We think that it is possible to make such interpretations that statistically the collective behaviour indicates about behaviour of individuals. It is possible to say that at least an average person (even if such average person in respect to all observed characteristics does not exist) would behave like the major trends in the Wikipedia indicate. We think that it is also possible to focus on behaviour of representatives of a group that share same characteristics that can be measured and identified. Thus in our work we try to propose idea that the *collective activities* done by various alternative subgroups of people can offer way to model at least on coarse level even individual knowledge management and thinking processes of each individual belonging to those subgroups. We expect that by analysing the knowledge structures of the Wikipedia it can be possible to find significant statistical features and build models about individual knowledge processing and to support learning with these models once they have been implemented in computerized tools that fruitfully automate operation of the models in real educational life to support the needs of individual learners. With the assistance coming from these new advanced systems learners can also begin to assist each other with their complementing strengths and building learning material for future generations.

According to Janssen et al. (2008) a *learning path* describes a structure of actions a learner has to perform in order to attain a competence or a competence profile. In our proposal the learning paths can be represented with concept maps and other conceptual networks and educational exploitation of learning paths can be carried out by exploring diverse routings in these networks by chained traversing of links from concept to concept. In our research we are interested in methodology related to semantic navigation, intelligent tutoring systems and content-based filtering.

With swarm intelligence, spontaneous indirect coordination between agents can show optimal learning paths with a form of *self-organization* called stigmergy (Gutiérrez et al. 2006). Similarly, we think that automated generation of favourable learning paths can be effectively based on proceeding in the conceptual network represented by Wikipedia articles and inter-article hyperlinks. Graph based visualizations relying on ontologies extracted from the Wikipedia have been proposed for education ((Dicheva & Dichev 2007); (Yang et al. 2007)). We now suggest extending the use of ontologies extracted from the Wikipedia to be applied in building personalized learning paths. This poses requirements to assess the quality of articles and perspectives that they can provide.

Supporting *knowledge acquisition* of a learner faces typical challenges of decision-making and creative problem solving and due to complex dynamic nature of human learning processes are hard to predict and evaluating solution candidates is often costly. We think that educational methods can get useful influence from various domains, such as strategic planning, game theory and stochastic network models. Important results are that Muller games having winning condition relying on states visited infinitely often are optimally determined with *finite-memory strategies* (Dziembowski et al. 1997) and that

winning conditions for parity games played on pushdown graphs can be realized also by *pushdown automata* (Walukiewicz 1996/2001). Some games, such as concave games and games with regret minimization, tend to converge to a *Nash equilibrium* ((Even-Dar et al. 2008); (Nadav & Piliouras 2010)).

Associations involving short time windows have been effectively modeled with *artificial neural networks* but for learning longer temporal relationships specific memory structures have been proposed (Starzyk & He 2009). With hidden Markov models Boyer et al. (2010) automatically extracted human tutoring modes having significant correlations with student learning outcomes. Duran and Monereo (2005) identified sequences of activities governing the exchanges present in peer tutoring of written composition task. Hou et al. (2008) identified sequential patterns present in asynchronous discussions used for problem solving and knowledge construction.

To better understand underlying characteristics of the Wikipedia and how they could be fruitfully exploited to support learning we considered that it is important to evaluate the role of *vocabulary* as a mean for conveying information and building cumulative, chainable and crosslinked knowledge. In linguistics a term *lexicon* is commonly used to refer to vocabulary to highlight its contrasting role to *grammar*. We tried to get insight about the various ways to formulate knowledge and perspectives that can be taken to this knowledge by gathering few alternative complementing *high-frequency word lists*. Typically a high-frequency list about a text sample shows each distinct word occurring in this sample in descending order in respect to its frequency of occurrences. Since childhood and adolescence constitute a period of life having a great rate of adoption of new knowledge and relating it to previous knowledge, we wanted to observe this gradual change in vocabulary. We think that it is possible to identify and define locally specific high-frequency word lists that summarize relatively reliably core factual content about certain knowledge entity.

We think that high-frequency word lists can be successfully used as condensed representations to describe learning content on various levels of detail, such as describing for example the main themes of a full semester course, or more specific topic covered during a single one-hour lecture, or giving a compact definition in one phrase to answer student's question, or any other educational entity in addition to these examples. To address the *needs of the learner* when she becomes exposed to new knowledge and is expected to be able to fruitfully relate new knowledge to her prior knowledge we think that successful educational practices should take well into account the way she has conceptualised her previous knowledge and additionally her personal characteristics concerning age, gender, cultural and ethnic background, temperament, hobbies, interests and other features of personality. Therefore we suggest that high-frequency word lists can be a valuable way to model the learner's process of evolving conceptualization and adoption of new knowledge.

For us, it seemed natural to extend the idea of high-frequency word lists to *high-frequency link lists*. Thus we think that to summarize core factual content about certain knowledge entity even further, it is possible to identify and define most meaningful conceptual relationships (i.e. high frequency links) between a set of concepts (i.e. high-

frequency words) describing that entity. To have increased value, these relationships could be supplied with a statement defining the nature of relationship.

As already mentioned above we have decided to focus in our further analysis only on those Wikipedia articles which are titled with a *common noun* (please note that in this dissertation with term “common noun” we specifically mean a noun that is typically written with a small initial letter and is opposite of a “proper noun”, i.e. term “common noun” does not mean just any commonplace noun). Despite of some limitations coming from excluding from our analysis other Wikipedia articles than those dealing with common nouns, it still seems fruitful in such respect that now analysis about linkage between articles can be considered to focus conveniently on verb based relationships between nouns. We think that this kind of semantically fixed perspective simplifies analysis and helps to guarantee that the results of analysis can be semantically reliable. For clarity reasons, it should be emphasized that later in this text when using a broader and less precise term high-frequency word list we are typically referring to a list containing only common nouns.

Even if we want ultimately to develop computational methods that can in very fine levels of detail adaptively support learning for any individual learner with her unique characteristics altogether, we think that with current incomplete understanding about possibilities of computational and psychological modeling it is practical to rely on methodology that somehow coarsely categorizes learners and learning content, and creates a mapping between the current features of the member belonging to a certain *category of learners* and recommendable next activities for her. We believe that one coarse way to categorize learners can be based on age of student so that for each annual age group a specific learning content is defined taking into account cumulative growth of knowledge so that new learning content requires that all previous learning content has been first sufficiently adopted. Besides categorization based on *age of student* we think that somewhat related categorization based on *language ability level* reached so far by student is very useful. We think that this current need for categorization and thus handling learners and learning content in bigger and somewhat discrete chunks can be seen as a similar kind of combination of advantage and challenge as developing learning content through collective process that averages the content. There is a need to find alternative and more advanced methodology to model and deal with learners and learning content but due to cost-efficiency for our current research we decided to accept the challenges of the classification and averaging with our current methodological approach.

3.8. Approaching learning with various levels of knowledge entities

Motivated by emergence of *small-world topology* in human brain networks (Wang et al. 2010) and in the Wikipedia (Ingawale et al. 2009) as well as indications about *scale-free properties* possibly in human brain networks ((Bullmore & Sporns 2009) referring to ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008); (Achard et al. 2006); (Bassett et al.

2006))) and more surely in the Wikipedia ((Zesch & Gurevych 2007); (Masucci et al. 2011)) we think that the knowledge structures represented in human mind have some analogues with information structures existing already currently in the Wikipedia online encyclopedia, and possibly also elsewhere in the World Wide Web (i.e. the Web) and its indexed web page collections. These emerging analogues give for us motivation to hypothesize that knowledge structures and processes of human mind can be relatively well mimicked even with just simple preliminary computational models. We suggest developing new computational models and tools to support education based on structural correspondence between the knowledge represented by the Wikipedia and interlinked corpus used by humans.

It has been estimated that there are well over 54000 *word families* in English (Nation & Waring 1997). Furthermore, Kuhn and Stahl (1998) mention based on previous research that people in school are exposed to 88700 different word families between kindergarten and grade 12 (Nagy & Andersson 1984) and that people learn about half of them which is about 45000 words or about 3000 word meanings per year ((Graves 1986); (White et al. 1990)). Lehr et al. (2004) mentions based on previous research that it has been estimated that there are 88500 distinct word families in school texts between grade 3 and grade 9 (Nagy & Andersson 1984). It has been suggested by Nation and Waring (1997) that a five-year-old child has a *vocabulary* of about 4000–5000 word families and then the vocabulary grows yearly with about 1000 word families for a native speaker until a university graduate has about 20000 word families. On the other hand, it has been estimated that a college student has a vocabulary of about 16785 words (D’anna et al. 1991). It has been suggested that knowing 95 percent of words in text can be sufficient for reasonable comprehension and that this can be reached with a vocabulary of 3000–5000 word families or just 2000–3000 word families ((Nation & Waring 1997) referring to (Laufer 1989)). Hsu (2009) has suggested that generally the proportion of words to word families is in range 1.54–2.18.

To create linguistic and semantic models with a systematic foundation, it has been considered useful to collect a collection of carefully balanced samples of varied texts and speech that form *corpuses* (i.e. corpora). Corpuses enable computing frequency lists of words and thus making assumptions of their relative significance. Even if it has been argued that semantic analysis should not give too much weight just for simple ranked word frequency lists we anyway think they can usefully facilitate prioritizing educational work. Before the emergence of facilitating computational resources an ambitious early work about word frequency lists has been presented by Thorndike (1921). One respected corpus of the English language is *British National Corpus* (BNC) built in 1991–1994 consisting of about 100 million words with 90 percent based on texts and 10 percent on speech ((Leech et al. 2001); (British National Corpus XML edition 2007)). It was estimated that a subset of about 86 million words of British National Corpus (BNC), consisting of words that occur at least 100 times in BNC, contains 30297 different words or 14011 different lemmatized words (Chujo 2004).

We believe that learning can be fruitfully supported by developing computer-assisted methods for exploiting the Wikipedia as an educational resource and this belief is motivated by promising possibilities to model *learning process* by comparing and

paralleling the building processes of knowledge structures in the Wikipedia and in the individual learner's mind as well as in her learning community. Since *English language edition of the Wikipedia* (<http://en.wikipedia.org>) is clearly the biggest edition and suited for internationally communicated research, we have focused our analysis on English language edition of the Wikipedia but we expect that our proposals could be reasonably well applicable to other language editions as well. Since the foundation in 2001 the English version of the Wikipedia has grown to contain about 4.3 million articles as of June 2013 (Wikipedia statistics 2013), each article defining a concept corresponding to the article title, and thus together all these articles supplied with hyperlinks can be considered to form a crosslinked vocabulary of 4.3 million concepts.

For educational purposes *Simple English edition of the Wikipedia* (<http://simple.wikipedia.org/>) containing about 93000 articles as of June 2013 (Wikipedia statistics 2013) has an advantage that it is specifically tailored to represent knowledge content with simple vocabulary and grammar, and we think that it offers a useful resource, but since English language edition has much wider coverage our analysis focuses on English language edition. Anyway we think that along growth Simple English edition can offer increasing level of coverage and can be used fruitfully in parallel with English language edition to complement available perspectives to knowledge.

In 2001 it was estimated that the *World Wide Web* contained at least 550 billion documents, most of them in non-indexed part of the web (Bergman 2001), and that in January 2005 the indexed part of the Web contained 11.5 billion pages (Gulli & Signorini 2005). Fletcher (2012) reports referring to (Alpert & Hajaj 2008) that currently dominating search engine company Google had apparently identified one trillion distinct web addresses by year 2008 but it is estimated to have actually indexed about 40 billion web pages, and that several billion new web pages appear to World Wide Web daily. Fletcher (2012) argues that the Web offers extraordinary accessibility, quantity, variety and cost-effectiveness of machine-readable text for research about natural language processing, information retrieval and text mining.

The growth of *human knowledge* on population level has been accumulating along the recorded history and innovations in data storage, duplication, sharing and communication has helped to increase access and adoption of knowledge on individual level. It has been estimated that in 1993 only 3 percent of information in the world was stored in digital format, in 2000 the degree was 25 percent and in 2007 already 94 percent (Hilbert & López 2011). It has been estimated that during year 2003 the total amount of information stored on four major recording media (paper, plastic, optic and magnetic media) was 5608991 terabytes and flow of transmitted information (through television/radio, telecommunication and Internet) was 17876397 terabytes, and correspondingly during year 2008 stored information was 14716464 terabytes and information flow was 31327710 terabytes (Bounie & Gille 2012). If we assume that each 2 kilobytes of information corresponds to one typewritten page having thickness of 0.1 mm, the estimated amount of stored information in 2008 corresponds to about 7.36×10^{15} typewritten pages which means a stack of paper that is 736000000 kilometers high that could go 960 times from Earth to Moon and back.

A full collection of articles belonging to the English version of the Wikipedia can be represented in a downloadable format of about 10 gigabytes as of August 2013 (<http://dumps.wikimedia.org/enwiki/20130805>) and although this data size is relatively manageable for many commonly used computational devices it seems to us that identifying recommendable exploration paths for a student on the request based on computational analysis of article data typically leads to some delay due to heavy computation and thus is often balanced with pre-processing of the data or limiting analysis to a subset of all articles or to certain features of each article ((Mihalcea & Csomai 2007); (Milne & Witten 2008b)).

The size of human vocabulary and the number of articles of the Wikipedia just discussed above can be contrasted with the neural structure of the *human brain* in which information is processed in a network consisting of neural cells called neurons. It has been estimated that a human brain contains about 86 billion neurons (Azevedo et al. 2009).

We have drawn together above mentioned values to Table 3.1 to enable approximated comparison between the size and coverage of various information sources thus letting to coarsely compare the growth of vocabulary of a human individual and the amount of articles in the English edition of the Wikipedia and the size of the World Wide Web. Please note that further observations about many suggested measures concerning learning are presented in Chapter 11. We here assume that each new *article* submitted to Wikipedia defines a *concept* denoted by its title and thus the descriptive article text as well as its hyperlinks to other articles (concepts) offer some kind of reasonable abstract resemblance to the process how a new concept is successfully understood and adopted into a human's vocabulary. To have an estimate about connectivity between concepts we have calculated the number of directed links L between N articles of Wikipedia English edition using the relation $L=N^{1.4}$ mentioned by Zlatic et al. (2006).

Due to encyclopedic characteristics of the Wikipedia the title of a Wikipedia article is typically represented in a form that resembles a noun, usually substantives, or at least a group of words that can be considered to sufficiently resemble noun. High dominance of nouns as the titles of the Wikipedia articles is fruitful for our aim to parallel knowledge structures of humans and the Wikipedia since Gentner and Boroditsky (2009) mention based on earlier research that there is a noun dominance in children's early word learning in both language production ((Gentner 1982); (Huttenlocher 1974); (Nelson 1973)) and comprehension (Goldin-Meadow et al. 1976).

We think that it is practical to emphasize in our further analysis especially those Wikipedia articles that describe a concept belonging to universally shared *everyday vocabulary* of language. Thus we have decided to focus on common nouns, and we have decided to avoid proper nouns (often dealing with organizations, locations, entertainment industry etc.) and various kinds of special pages and for example lists and category pages. Since the Wikipedia contains a lot of articles describing about other topics than common nouns we have supplied the Table 3.1 also with an estimate about the amount of Wikipedia articles having titles that can be considered as common nouns. We have generated this estimate based on a random sample of 1000 Wikipedia articles

that turned out to have 138 titles considered as common nouns, thus suggesting that about 13.8 percent of Wikipedia articles describe a topic titled with a common noun. In the comparison shown in Table 3.1 it seems that when considering each Wikipedia article to represent a concept the English Wikipedia has greatly exceeded the average vocabulary of an educated adult. This hypothesis gets some support from our analysis discussed in Subchapter 12.2 suggesting that as of June 2013 the Wikipedia contains about 5200 times more unique hyperlinks and about 14 times more unique nouns in unique hyperlinks than is required to cover general vocabulary having over 54000 word families (Nation & Waring 1997).

However even if the Web and its subsections have some intellectually favourable features that are not yet fully understood and the future research hopefully can enable exploiting these features to support understanding human thinking, it needs to be remembered that these features do not necessarily reveal the fundamental architecture of *semantic meaning* but merely reflect the design considered appropriate by the humans at the time of building these knowledge structures. So when studying for example knowledge structures of the Wikipedia we cannot expect to access fundamental results about how concepts are or should be organized in our universe but instead we can see how the current populations containing individuals with varying agendas build knowledge structures.

Therefore research about semantics in the Wikipedia has strong flavor of research of sociology and anthropology, and we can hope that progressively research efforts done on wide scale of domains of research will make conceptual and semantical models more accurate even if it may never become possible for our species to fully understand the intelligence implemented in our neural system. Anyway research about human mind seems to be a fascinating domain of research since it means that after extremely long evolution of life one of its species is actively trying to understand its own mental processes and the characteristics that have actually enabled this species to gain its dominant position on the Earth. Research trying to model human knowledge actually aims to solve the mysteries that govern the most fundamental processes of the evolution and reasons of life itself and its meaning.

Table 3.1. Comparison of sizes of some information structures (further observations about many suggested measures concerning learning are presented in Chapter 11).

<i>Information structure</i>	<i>Number of units</i>
Human vocabulary (unique word families or words)	<p><i>5-year-old child:</i> 4000–5000 word families (Nation & Waring 1997);</p> <p><i>adult:</i> 20000 word families (Nation & Waring 1997); 16785 words (D’anna et al. 1991); 45000 words ((Kuhn and Stahl 1998) referring to ((Graves 1986); (White et al. 1990)));</p> <p><i>reasonable 95-percent level comprehension:</i> 3000–5000 word families or just 2000–3000 word families ((Nation & Waring 1997) referring to (Laufer 1989))</p> <p>proportion of words to word families in range 1.54–2.18 (Hsu 2009)</p>
Words occurring at least 100 times in British National Corpus (based on a subset of about 86 million words)	30297 different words and 14011 different lemmatized words (Chujo 2004)
Word families in English	Well over 54000 (Nation & Waring 1997)
Word families student can encounter in school texts	88700 words families between kindergarten and grade 12 ((Kuhn & Stahl 1998) referring to (Nagy & Andersson 1984)); 88500 word families between grade 3 and grade 9 ((Lehr et al. 2004) referring to (Nagy & Andersson 1984))
Articles and hyperlinks in the English edition of the Wikipedia as of June 2013	4300000 articles (Wikipedia statistics 2013); 1900000000 hyperlinks (based on estimated formula (number of articles) ^{1.4} (Zlatic et al. 2006)); 590000 articles about common nouns (based on an estimated formula $0.138 \times (\text{number of articles})$ as explained in main text of Subchapter 3.8 by the author)
Indexed web pages of the World Wide Web in 2008	40000000000 ((Fletcher 2011); (Google 2008))
Identified web addresses in 2008	100000000000 ((Fletcher 2011); (Google 2008))
Information stored on four major recording media (paper, plastic, optic and magnetic media) in 2008	14716464 terabytes (Bounie & Gille 2012) corresponding to about 7.36×10^{15} typewritten pages
Neurons in a human brain	86000000000 (Azevedo et al. 2009)

3.9. Sample high-frequency word lists and conceptual relationships for students

To develop new computational and educational models relying on high-frequency word lists and high-frequency link lists, we gathered a set of *high-frequency words* that are typical for a student and her conceptualization about vocabulary dealing with her everyday life and her personal perspective towards it. Along the growing age and maturity of student the collection of high-frequency words can be expected to progressively change to handle more and more abstract and complex meanings. We

think that there is need to identify high-frequency words for several consecutive levels of age and maturity of student, and especially in early life (about years 0–25) that offers dramatic expansion of knowledge to an individual human.

Word frequency effect has been noted so that people respond more quickly to high-frequency words of a language than low-frequency words of a language in respect to for example lexical decision, reading aloud, semantic categorization and picture naming (Duyck et al. 2008). To model human learning mechanisms, measuring word identification latency has been useful often carried out with lexical decision tasks (person decides if a shown letter string is a real word) or naming tasks (person names aloud a presented word) and can be motivated by word frequency, like in serial-searched rank frequency models, threshold activation models and connectionist models, and contextual diversity (Johns & Jones 2008).

Age of acquisition effect has been identified both in native language acquisition and secondary language acquisition meaning that words learned earlier in a person's life can be recognized and produced more quickly than words learned later in life and it has been suggested that mappings between orthographic, phonological and semantic representations of words form a network that support later reconfigurations for new associations but still favour connections learned early in language acquisition ((Izura & Ellis 2002); (Ellis & Lambon 2000)).

An interesting phenomena related to suggested *peaking of learning potential* during early years of life is experience of acceleration of passing of time along maturing of an individual and this has been explained so that apparent length of year is inversely proportional to a person's actual age (Morrison 1991) and one suggested formula to calculate one's effective age EA based on actual age t is $EA=80 \times \ln(t+1)/\ln(81)$ motivated by integral analysis of $\int_0^t \delta/(t+\epsilon) dt$ with conditions $t=0: EA=0$ and $t=80: EA=80$ (Pi 2001). Anyway we believe in life-long learning and that everyone has important unique abilities that deserve appreciation and learning potential can be greatly supported with positive attitude and encouraging environment.

In our research we decided to emphasize analysis on *teenaged students* but we believe that our findings and modeling that we make with this age group can to some extent apply for students in other age groups as well. One of the reasons to emphasize teenaged students was that we expected that in our experiments it was more easy to reliably convey the goals of our educationally motivated empirical tasks to relatively mature students than younger students (or younger children) and then to evaluate and model more reliably their learning processes.

To gather a set of high-frequency words for teenaged students we carried out an *experiment* with a group of 103 students having ages ranging from 15 to 18 years and having learning abilities that can be considered normal. An overview of this experiment has been published in publication [P9] and we present here now extended more detailed results. The students represented relatively diverse cultural backgrounds and school performance and some of them used in our experiment English language besides Finnish language but majority used Finnish language. In this experiment we asked each student to freely associatively write a list of 20 most important concepts (only common nouns) concerning topic "life" (it was ordered that the concept "life" itself should not be

mentioned in the list). Then we asked everyone to review his generated list and give each concept a ranking value representing “measure of importance” ranging from 1 to 20 (value 1 meaning the most important). Then we asked each student to draw a concept map by adding in a free ordering all the concepts to a paper and connecting with a non-directional line the most important connections between these concepts according to her intuition (thus linking direction was not specified when defining relationships between a pair of concept). Based on all of these concept maps we were able to generate *high-frequency word lists* and *high-frequency link lists* representing an approximated average conceptualization of knowledge of these students. Naturally, there are many alternative ways to define rankings for words and links. The set of associative conceptual relationships that we gathered experimentally from students in our research can be contrasted with some previously gathered collections of associative pairs of concepts including The University of South Florida Free Association Norms (Nelson et al. 2004) and Edinburgh Associative Thesaurus (Kiss et al. 1973) and with associative networks that we discussed in Subchapter 3.3. In our experiment the students (n=103) generated 621 unique nouns that had together 1777 occurrences.

We think that high-frequency word lists and high-frequency link lists enable us to define a conceptual frame for the *knowledge structure* typically held by a teenaged student and that helps to position the requirements for setting the learning goals that could rely on exploiting the large conceptual knowledge available in the Wikipedia in a fruitful way. We expect that every group of students will naturally generate somewhat different average high-frequency word lists and average high-frequency link lists. Especially we expect that along the learning process and maturing of student these lists can be seen evolving and possibly there are some shared trends of evolution and possibly these lists reach towards a conceptualization that can be considered to be somewhat a consensus of grown-ups about viewpoint on life. However we expect that in accordance with idea of life-long learning the evolution of these lists remain active through an individual’s whole life enabling her always to excel herself further.

A central theme for our research is to propose that traversing in conceptual network structures resembling hyperlink network of Wikipedia can be useful for adoption of knowledge that has been selected as a topic to become learned and our research aims to offer some kind of recommendations concerning what kind of traversing methods could be useful. In our research we decided to contrast conceptual structures existing in hyperlink network of Wikipedia and generated by traversals in hyperlink network of Wikipedia made by learners with conceptual structures existing in the minds of learners.

My aim was to estimate how traversing in hyperlink network of Wikipedia made by learners and the conceptual structures received into learners’ minds during these traversals can be connected to and merged with the conceptual structures existing in learners’ minds already before the traversals. I considered that to approach this research goal a natural starting point was to gather a collective associative network. Please note that we mentioned some previous research about associative networks in Subchapter 3.3. We asked each individual belonging to a group of 103 students to create a personal conceptual network generated based on his own free association (i.e. a personal associative network) and we combined all these individual conceptual networks (n=103)

to form a collective conceptual network (i.e. a collective associative network). Then we contrasted conceptual structures existing in hyperlink network of Wikipedia and generated by traversals in hyperlink network of Wikipedia made by learners with that just mentioned collective associative network, so not with a personal associative network although it might be possible to be done in some other research.

My motivation for using collective associative network in comparison with existing and traversed hyperlink network of Wikipedia is that collective associative network enables to make an estimation about an average personal associative network of student and also to gain more diverse perspective based on merger of several personal perspectives. By combining personal associative networks to form a collective associative network we could also easily and rapidly create a much larger associative network than each individual associative network alone were. In addition, when trying to make comparison with the Wikipedia having contents and link structure generated in collective work, it seemed most natural to compare collective association network of the Wikipedia with collective associative network of students. Furthermore conceptual structures generated by traversals in hyperlink network of Wikipedia made by learners were especially collectively created and thus also comparison of them with collective associative network of students remained naturally on collective level.

In two tables, Table 3.2 and Table 3.3, is shown a sample of the highest-ranking common nouns (or other sufficiently resembling groups of words that according to us can be considered as common nouns) from some alternative ranking-driven word lists and lists of Wikipedia articles based on previous research and empirical data that we have gathered experimentally. If original word lists include other part-of-speech (or other Wikipedia pages) than those that we considered as common nouns we have supplied each concept in both Table 3.2 and Table 3.3 with a ranking value indicating the ranking position of current concept among all part-of-speech (or all Wikipedia pages).

In Table 3.2 as well as often in further analysis presented in this publication, if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is an average of all ranking values that would have been used if there were not need for sharing the position, and then again corresponding number of ranking values are skipped. We use suffix “-s” after the ranking value to indicate that it is a shared ranking value. For example frequencies 100, 90, 90, 80 and 70 would generate corresponding ranking positions 1, 2.5s, 2.5s, 4 and 5 (here 2.5 is motivated by calculation $(2 + 3)/2 = 2.5$). We decided to use this average ranking value approach since having lots of shared ranking positions makes distributions of ranking positions in parallel ranking listings to differ so much that comparison becomes difficult, and also when using statistical comparison tests this average ranking value approach is beneficial. Like for all decimal values in English text of this dissertation the decimal mark is indicated with a dot (not a comma).

The first and second column of Table 3.2 show based on *Oxford Wordlist* a few most frequently used common nouns in writing and speech by children attending school level Preparatory (Lo Bianco et al. 2008), based on 1891 writing samples, and children attending school level Year 4 (Bayetto 2010), based on 1251 writing samples, here

school levels labeled somewhat confusingly since level Year 4 means the fifth school level. We did not have access to any part-of-speech classification concerning Oxford Wordlist and thus we self selected based on our own intuition which concepts we considered as common nouns in our further analysis and to be included in Table 3.2. In addition we did not have access to complete frequency values of Oxford Wordlist and thus we cannot use them in our further analysis and cannot provide them in Table 3.2. Furthermore, ranking values are given here in a consecutive manner even if some concepts of Oxford Wordlist may share same frequency value and thus also same ranking position which seems possible due to sequentially emerging alphabetical ordering in Oxford Wordlist.

The third and fourth column of Table 3.2 show highest-ranking words (only common nouns) we gathered in our experiment from teenaged students when they were asked to list and rank most significant vocabulary of 20 nouns concerning topic “life” (explained originally in publication [P9]). The third column shows high-frequency words (only common nouns) with ranking based on occurrences in word lists generated by students (each student could mention each concept at most once in her word list), full listing is available in Appendix P. The fourth column shows high-frequency words (only common nouns) with ranking based on sums of measures of importance originating from ranking given by each student for the words she generated to form her word list (ranking values originally given by students in ascending range from 1 to 20 were translated to an inverse descending range of measures of importance from 21 to 1, thus greater value now indicating more important), full listing is available in Appendix Q. For both third and fourth column the following rule applies: if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position, and for each concept at most one occurrence is counted per student.

The fifth column of Table 3.2 shows a few most frequently occurring common nouns in British National Corpus (BNC) containing 100 million words of samples of English language of which 90 percent is based on texts and 10 percent based on speech. We have gained these nouns from a lemmatized word list of British National Corpus provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>).

When comparing all five columns of Table 3.2 it seems that rankings based on vocabulary of children, vocabulary of teenagers and vocabulary of general language in BNC (and thus somewhat indirectly emphasizing vocabulary of adults) have important complementing alternative perspectives and foci (i.e. focuses) on language and conceptualization of phenomenon of everyday life. Observing this gradual change in emphasis of word rankings in consecutive age groups seems to support our idea of assisting student’s learning with adaptive high-frequency word lists that can progressively introduce new concepts.

Table 3.2. A few most frequently used common nouns in writing and speech by children attending school level Preparatory and children attending school level Year 4 (meaning fifth school level) based on Oxford Wordlist, highest-ranking common nouns gathered in current research from teenaged students with ranking based on occurrences in word lists generated by students and based on sums of measures of importance given by each student, and a few most frequent common nouns in British National Corpus.

Oxford Wordlist (school level Preparatory) (Lo Bianco et al. 2008)	Oxford Wordlist (school level Year 4) (Bayetto 2010)	Word lists of teenaged students (n=103) based on occurrence (Appendix P) (* = several concepts, due to space constraints shown in Appendix P)		Word lists of teenaged students (n=103) based on sum of measures of importance (Appendix Q)		Lemmatized words in British National Corpus (Kilgarriff 1997)	
concept (ranking among all part-of-speech)	concept (ranking among all part-of-speech)	concept (ranking)	number of occurrences	concept (ranking)	sum of measures of importance	concept (ranking among all part-of-speech)	number of occurrences
weekend (15)	day (31)	family (1)	53	family (1)	903	time (53)	183427
dad (21)	mum (40)	friend (2)	49	friend (2)	821	year (60)	163930
home (27)	time (46)	work (3)	41	love (3)	525	people (80)	125430
house (28)	home (50)	death (4)	40	work (4)	445	way (89)	112636
mum (29)	house (55)	love; school (5.5s)	33	water (5)	408	man (101)	97985
time (32)	going (58)	food; water (7.5s)	31	food (6)	396	day (104)	92699
day (34)	school (63)	animal (9)	29	death (7)	363	thing (115)	77612
play (40)	dad (66)	human (10)	24	school (8)	362	child (121)	71008
park (46)	can (80)	birth (11)	23	human (9)	335	government (133)	66894
birthday (47)	people (81)	nature (12)	21	birth (10)	321	part (135)	65773
Saturday (48)	will (82)	home (13)	18	nature (11)	303	life (137)	64423
party (52)	friends (93)	child; joy; sun (15s)	16	animal (12)	285	case (140)	63577
Sunday (54)	name (96)	dog; hobby; house (18s)	15	home (13)	237	woman (141)	63087
dog (55)	night (100)	education; health; money; sorrow; study (22s)	14	health (14)	225	work (146)	62248
brother (60)	bed (104)	computer (25)	13	sun (15)	224	system (149)	61912
football (69)	girl (111)	plant (26)	12	child (16)	202	group (155)	60689
friends (71)	door (113)	car; happiness; tree (28s)	11	joy (17)	195	number (156)	60607
can (72)	play (119)	book; cat (30.5s)	10	hobby (18)	188	world (161)	59094
love (74)	look (124)	air; clock; learning; mother; summer; television (34.5s)	9	study (19)	186	area (162)	58449
zoo (76)	morning (126)	living; music; party; religion (39.5s)	8	happiness (20)	179	course (164)	57776
school (79)	thought (134)	*	7	education (21)	172	company (165)	57754
playing (86)	dog (136)	*	6	house (22)	147	problem (168)	56483
night (88)	car (138)	*	5	plant (23)	136	service (173)	54468
bed (89)	way (140)	*	4	mother (24)	133	hand (176)	53265
shop (90)	game (147)	*	3	money (25)	130	party (177)	52979
bike (92)	water (153)	*	2	air (26)	121	school (181)	52227
dinner (93)	room (154)	*	1	dog (27)	118	place (184)	51537
car (98)	black (157)			world (28)	106	point (190)	49187
fish (99)	family (158)			father; living (29.5s)	105	house (191)	49022
beach (101)	brother (160)			sorrow (31)	104	country (193)	48177
sister (105)						week (196)	47512

Table 3.3 part 1 of 2 (starts here and continues on next page). Some of the highest-ranking Wikipedia articles having a title corresponding to a common noun in respect to trying to represent the most viewed article, the most edited article, the longest article in respect to file size and the most referenced article in respect to receiving links from other articles.

Most viewed articles in 2008 based on 210 analyzed days (Wikistics Falsikon 2009)		Most edited articles as of 30 July 2011 at 22:56 UTC (Wikipedia's pages with most revisions 2011)		Longest articles based on file size as of 29 July 2013 at 17:25 UTC (Wikipedia's long pages 2013)		Most referenced articles based on incoming internal links from articles (Wikipedia's most referenced articles 2011)	
article (ranking among all pages)	number of views (page hits) per day	article (ranking among all pages)	number of edits (revisions)	article (ranking among all pages)	file size in bytes	article (ranking among all pages)	sum of direct links and links via redirects arriving from other articles
wiki (5)	140550	World War II (118)	21552	Plasmodium falciparum biology (9)	369920	geographic coordinate system (1)	662158
sex (17)	40141	Catholic Church (124)	21163	2000s (decade) (17)	325203	International Standard Book Number (3)	272923
2008 Summer Olympic Games (22)	28627	2006 Lebanon War (143)	19256	Golden Eagle (20)	314623	music genre (5)	191980
World War II (39)	21020	global warming (151)	18636	impalement (30)	304675	time zone (6)	190736
vagina (40)	20634	Jehova's Witnesses (159)	17994	British literature (49)	280880	biological classification (7)	186918
penis (44)	19773	European Union (172)	17180	Iran-Iraq War (63)	268135	record label (9)	180716
masturbation (55)	18189	Islam (174)	17107	plug-in electric vehicle (68)	266102	animal (15)	138365
global warming (59)	17577	Christianity (183)	16575	Gaza War (71)	265224	association football (17)	125106
anal sex (63)	17327	Hurricane Katrina (188)	16490	Euro zone crisis (79)	262361	binomial nomenclature (18)	124074
love (64)	17297	anarchism (204)	15905	sexuality in ancient Rome (80)	262267	record producer (20)	110761
sexual intercourse (65)	17190	September 11 attacks (207)	15851	Roman Empire (87)	261014	World War II (21)	109653
World War I (66)	17033	Iraq War (250)	14308	history of Western civilization (92)	258988	daylight saving time (22)	106392
Halloween (69)	16890	Scientology (253)	14261	War in Afghanistan (2001-present) (106)	254038	digital object identifier (27)	86406
pornography (79)	15776	Gaza War (256)	14221	Catholic Church and Nazi Germany (107)	253978	village (30)	77282
Olympic Games (80)	15751	World War I (267)	13988	Genie (feral child) (111)	252703	English language (31)	77087

Table 3.3 part 2 of 2 (started on previous page and continues here).

Most viewed articles in 2008 based on 210 analyzed days (Wikistics Falsikon 2009)		Most edited articles as of 30 July 2011 at 22:56 UTC (Wikipedia's pages with most revisions 2011)		Longest articles based on file size as of 29 July 2013 at 17:25 UTC (Wikipedia's long pages 2013)		Most referenced articles based on incoming internal links from articles (Wikipedia's most referenced articles 2011)	
article (ranking among all pages)	number of views (page hits) per day	article (ranking among all pages)	number of edits (revisions)	article (ranking among all pages)	file size in bytes	article (ranking among all pages)	sum of direct links and links via redirects arriving from other articles
Thanksgiving (88)	15368	cannabis (drug) (270)	13959	Russia-Georgia War (122)	249273	studio album (32)	76866
canine reproduction (92)	15092	Buddhism (291)	13442	international reaction to the Gaza War (155)	244210	county seat (36)	67442
2012 (104)	13747	evolution (304)	13256	Holocaust (162)	243428	unincorporated area (37)	67146
September 11, 2001 attacks (106)	13686	2007 (305)	13251	international reactions to the Libyan civil war (167)	241623	UTC+02:00 (38)	67013
oral sex (107)	13681	2008 (326)	12817	Syrian civil war (172)	240847	UTC+01:00 (47)	57675
Great Depression (115)	13258	Vietnam War (356)	12277	beta distribution (191)	236930	arthropod (48)	57235
2008 (121)	12815	The Holocaust (369)	12129	flight and expulsion of Germans (1944–50) (192)	235912	single (music) (49)	57103
orgasm (131)	12326	Intelligent design (371)	12114	Honorific nicknames in popular music (194)	235427	Central European Time (53)	54388
Valentine's Day (132)	12279	cat (372)	12106	Iraq War (202)	234211	insect (54)	54317
Europe (141)	11917	Hinduism (373)	12087	International Space Station (207)	232789	World War I (55)	53497
Christmas (142)	11853	Atheism (388)	11970	Srebrenica massacre (213)	231525	mayor (56)	53159
Internet (152)	11456	Virginia Tech massacre (390)	11926	Miscegenation (221)	230182	chordate (57)	52540
socialism (161)	11145	9/11 conspiracy theories (397)	11810	Suez crisis (224)	229661	Catholic Church (58)	52531
Seven Wonders of the World (164)	11061	Fascism (399)	11771	humanitarian response by national governments to the 2010 Haiti earthquake (226)	229380	defamation (59)	52291
Vietnam War (165)	11032	2008 South Ossetia War (422)	11540	Romance languages (240)	227523	city (60)	52081

In Table 3.3 four first columns show some of the highest-ranking articles having a title corresponding to a common noun from the Wikipedia in respect to trying to represent the most viewed article (Wikistics Falsikon 2009), the most edited article (Wikipedia's pages with most revisions 2011), the longest article in respect to file size (Wikipedia's long pages 2013) and the most referenced article in respect to receiving links from other articles (Wikipedia's most referenced articles 2011), in one frozen timeframe. Fifth column shows some of the highest-ranking common nouns of lemmatized word list of British National Corpus (Kilgarriff 1997).

A principal criterion when we selected articles considered as common nouns was to exclude all articles titled with a person's name or country-level geographical or administrative topics as well as organizational and commercial names. These four rankings of Wikipedia articles highlight how greatly varied perspectives are available to large knowledge content stored in the Wikipedia and that there is a lot of unleashed potential for developing adaptive methods for pedagogic exploration of articles of the Wikipedia but careful planning is needed to manage to develop methods that can guarantee educationally motivated quality in exploration.¹¹ Even if many high-ranking articles deal with a topic that some people can consider as intimidating or taboo (for example articles about sexuality and wars) we think that indeed the great interest in these topics according to the high-ranking position in article listings of Table 3.3 tells clearly that existence of these articles is very meaningful and publication and availability of their information is welcome and can help to reduce irrational and harmful superstition, prejudice and conflicts as well as to support healthy living, freedom of speech, peace and democracy.

Naturally each high-ranking list shown in Table 3.3 shows just one frozen timeframe in constant evolution of the Wikipedia and due to the practice allowing anyone to freely edit articles we think that any kind of high-ranking lists describing evolution of the Wikipedia are fundamentally vulnerable to vandalism and manipulation and thus they should be analyzed critically when trying to develop models about collaborative editing and reading practices.

Anyway, despite the fact that several ranking lists shown in Table 3.2 and Table 3.3 have varying origins, we think that comparing all these ranking lists can reasonably well offer an overview and insight to the emerging challenge of our research that tries to find educational methods addressing various alternative ways to conceptualize concepts of everyday life and to prioritize them in ranking based on diverse personal characteristics and viewpoint. Our aim is to find methods that enable supporting bridging the alternative conceptualizations so that new knowledge structures can be efficiently adopted and linked to the previous knowledge structures held by an individual learner.

Appendix E shows two alternatively computed high-frequency word lists of 110 highest-ranking common nouns of British National Corpus ((Kilgarriff 1997); (Leech et al. 2001)), relying on about 100 million word corpus, and similarly 110 highest-ranking common nouns of Corpus of Contemporary American English ((Davies & Gardner 2010); (Word frequency data from COCA 2013)), relying on about 400 million word corpus, that reveal together some variation in rankings of everyday vocabulary. We could not fully understand why in online frequency lists of Corpus of Contemporary

¹¹ Some additional high-ranking lists about evolution of the Wikipedia that can be used to identify *trends about topics* that are considered interesting for the users can be retrieved from lists that are listed in a list of lists of popular pages by WikiProject (http://en.wikipedia.org/wiki/Wikipedia:Lists_of_popular_pages_by_WikiProject), including for example a list of popular vital articles (http://en.wikipedia.org/wiki/Wikipedia:Vital_articles/Popular_pages) and a list showing most popular 25 articles weekly (<http://en.wikipedia.org/wiki/Wikipedia:5000/Top25Report>). Furthermore, interesting lists for emerging trends are a list trying to represent the most wanted articles (http://en.wikipedia.org/wiki/Wikipedia:Most_wanted_articles) and a list trying to represent the shortest articles (<http://en.wikipedia.org/wiki/Special:ShortPages>).

American English some of the frequencies did not seem to systematically descend along the provided rank position but anyway we decided to use these lists for our analysis. Especially comparison between rankings of British and American corpus highlights how in different cultural contexts different perspectives become emphasized in vocabularies and this kind of perspective differences offer a potential resource for modeling new computer-assisted educational methods to support adoption of new knowledge. For each of three lists the nouns are shown in descending order of frequency of occurrences in corpus. The number value in parenthesis after the word indicates position in ranking of all word classes (i.e. including also other word classes besides nouns).

3.10. Formation of conceptual networks for educational activities

Naturally there are many alternative ways to form conceptual networks for educational activities. Since we are strongly interested in exploiting knowledge structures of the Wikipedia for educational activities we think it is important to aim to parallel knowledge structures of the Wikipedia with knowledge structures representing conceptualization of students. To have a both compact and sufficiently representative collection of concepts in our further analysis we decided to focus specifically on a subset of words belonging to high-frequency words we have gathered from group of 103 teenaged students (as explained in Subchapter 3.9). We decided to select a subset of words with a requirement that each accepted word is mentioned in word lists of at least four different students (i.e. frequency of occurrences for each word in all word lists must be at least four) and each student could mention each concept at most once in her word list. We think that requiring at least four students to mention each selected word guarantees that selected word is collectively considered significant. When selecting from high-frequency words of teenaged students only those mentioned by at least four students we ended up having a subset of 102 highest-ranking concepts and in our further analysis we will refer to this specific subset of 102 concepts with a term *102 core concepts* (all of them belonging to word class of common nouns).

Please note that even if vocabulary size of 102 seems to offer relatively low sample size for analysis, it can still offer relatively good coverage (as we originally explained in publication [P9]). Group of students (n=103) generated 621 unique nouns that had together 1777 occurrences, and among these 1777 occurrences 102 highest-ranking nouns had 1067 occurrences (60 percent of noun usage of students). Thus since it has been suggested that 95-percent-level comprehension can be achieved with a vocabulary of just 2000–3000 word families ((Nation & Waring 1997) referring to (Laufer 1989)) we tried to estimate the coverage of our experimental vocabulary in lemmatized word list of British National Corpus (BNC) containing 6318 words occurring more than (or at least) 800 times in BNC (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>)). 102 highest-ranking nouns of BNC represented 5.8–6.0 percent among 2000–3000 highest-ranking concepts of any word

class of BNC and 27–29 percent among 2000–3000 highest-ranking nouns of BNC. Further analysis about coverage concerning vocabulary size of 55 is discussed in Subchapter 5.3.

Table 3.4 extends observations shown in Table 3.2 in columns three, four and five. Table 3.4 provides a more detailed comparison about the rankings of 102 core concepts in three alternative perspectives, as explained in the following. In Table 3.4 in columns 1–3 all 102 core concepts are shown in descending order of ranking based on occurrences in word lists generated by teenaged students and this ranking is contrasted with two other rankings shown in columns 4–5 and in columns 6–9. In columns 4–5 ranking is based on sums of measures of importance (originating from ranking given by each teenaged student for the words she generated to form her word list) on scale from 21 to 1, greater value indicating more important. In columns 6–9 ranking is primarily based on occurrences in lemmatized word list of British National Corpus (BNC) containing 6318 words occurring more than 800 times in BNC (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>)) and secondarily based on occurrences in non-lemmatized word list of British National Corpus containing 208656 word items occurring more than 5 times in BNC (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/all.num.o5>)). In ranking based on British National Corpus, frequency values were not available for “elderness”, “freetime” and “physical_training” since these concepts were not found either in lemmatized word list or non-lemmatized word list of British National Corpus occurring more than five times and thus a shared ranking value of 100s was given to these three concepts.

For both of these two contrasting ranking listings (i.e. sums of measures of importance and occurrences in British National Corpus) it is indicated in parenthesis how many positions higher the current word is in ranking when compared to the same word’s ranking based on occurrences in word lists generated by teenaged students.

Table 3.4 shows 102 core concepts in column 1 accompanied in parenthesis with the nearest corresponding article titles we managed to identify in the Wikipedia online encyclopedia if the exactly same phrasing was not found matching. For clarity, Appendix F shows all 102 core concepts both in English and Finnish due to the fact that part of vocabulary experiments in our research was carried out in Finnish even if we report the results in English. In addition, the listings in Appendix F highlight some decisions made about semantics of 102 core concepts to make translations coherent even if nuances are not directly visible in both languages in the same way.¹² Among 102 core concepts, when students generated concepts having two alternative meanings, like in cases “ground/earth” and “pen/pencil”, we decided to select only one option to

¹² Based on our experimentally gathered conceptual material from students we identified for each of 102 core concepts *one specific major meaning* that is then used in our further analysis. Since in English many concepts have often many alternative meanings we want to clarify here especially four meanings based on our experimental data: “dream” carries a specific meaning of an imagery during sleeping, and respectively “goal” means a result to achieve, “nutriment” means a source of nourishment and “young” means a young person. In addition “physical training”, even if containing two words, was considered as a concept due to original one-word Finnish concept “liikunta”. 102 core concepts includes concept “sister” which did not have directly corresponding article in the Wikipedia but instead article Sibling which was then used in our further analysis even if 102 core concepts did not include concept “brother”.

represent the current concept and the choice was done so that we selected the option which was positioned higher in the ranking of British National Corpus when comparing the positions of these two options currently in question. Please note also that our analysis about vocabulary collections and their linkage mainly focuses on nouns so that even if in some of our word listings for example word “love” can be considered either as a noun or verb we typically refer to a noun form.

An origin of challenge for our further analysis aiming to compare parallel conceptual relationships in concept maps generated by students and the hyperlinks in the Wikipedia comes from the fact that in some cases there were not well matching Wikipedia article available for each concept among concept maps. One example is that concept “friend” used in concept maps had to be coupled with concept Friendship in the Wikipedia and a specific significance for this disparity comes from the fact that in concept maps concept Friend seems to have strong position whereas concept Friendship does not seem to have as strong position and it remains partially unsolvable how largely this difference is caused by the disparity and how largely by other reasons. Other examples of unfortunate disparity between concept maps and the Wikipedia include couplings of concepts “air” versus Atmosphere_of_Earth, “cloth” versus Clothing, “elderness” versus Old_age, “succeeding” versus Management, “nutriment” versus Diet_(nutrition), “physical_training” versus Physical_fitness and “young_(person)” versus Adolescence.

The three rankings shown in Table 3.4 represent three different frequency distributions that can be compared in various ways. To compare the three rankings show in Table 3.4 we used *five statistical comparison tests* that can be flexibly used with various kinds of distributions: sign test of paired samples, bootstrap version of Kolgomorov-Smirnov two-sample test, Goodman-Kruskal gamma statistic, Spearman’s rank correlation coefficient rho and Kendall’s rank correlation coefficient tau. In computation of these tests some inaccuracies may have become introduced to results due to dealing with shared ranking values (i.e. rank ties). It has been suggested that Goodman-Kruskal gamma statistic manages well with data containing many shared ranking values. On the other hand, to make sign test of paired samples behave correctly tie differences (i.e. having shared ranking) and zero differences are excluded from analysis and then also the total number of paired samples is reduced respectively.

Table 3.4 part 1 of 3 (starts here and continues on next page). 102 core concepts with ranking based on occurrences in word lists of students, sums of measures of importance and occurrences in word lists of British National Corpus.

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgarriff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
family	53	1	903	1 (0)	42773	218	36	9 (-8)
friend (Friendship)	49	2	821	2 (0)	31927 (Friendship: 2353)	296 (Friendship: 3138)	75 (Friendship: 1552)	16 (-14)
work	41	3	445	4 (-1)	62248	146	14	4 (-1)
death	40	4	363	7 (-3)	22712	453	142	24 (-20)
love	33	5.5s	525	3 (+2.5s)	13921	741	288	44 (-38.5s)
school	33	5.5s	362	8 (-2.5s)	52227	181	26	7 (-1.5s)
food	31	7.5s	396	6 (+1.5s)	21044	488	161	27 (-19.5s)
water	31	7.5s	408	5 (+2.5s)	35767	261	57	13 (-5.5s)
animal	29	9	285	12 (-3)	15250	671	248	36 (-27)
human	24	10	335	9 (+1)	5612	1693	797	67 (-57)
birth	23	11	321	10 (+1)	5889	1615	753	65 (-54)
nature	21	12	303	11 (+1)	18223	570	201	32 (-20)
home	18	13	237	13 (0)	39850	235	40	10 (+3)
child	16	15s	202	16 (-1s)	71008	121	8	3 (+12s)
joy	16	15s	195	17 (-2s)	2740	2864	1401	78 (-63s)
sun	16	15s	224	15 (0s)	9558	1058	453	54 (-39s)
dog	15	18s	118	27 (-9s)	12406	823	336	45 (-27s)
hobby	15	18s	188	18 (0s)	906	5864	3021	91 (-73s)
house	15	18s	147	22 (-4s)	49022	191	29	8 (+10s)
education	14	22s	172	21 (+1s)	25987	386	113	19 (+3s)
health	14	22s	225	14 (+8s)	24527	405	123	20 (+2s)
money	14	22s	130	25 (-3s)	37892	247	50	11 (+11s)
sorrow	14	22s	104	31 (-9s)	536 (first) 683 (all)*	12603 (first)*	5579 (first)*	93 (-71s)
study	14	22s	186	19 (+3s)	32786	287	69	15 (+7s)
computer	13	25	99	33.5s (-8.5s)	16976	602	214	34 (-9)
plant	12	26	136	23 (+3)	14638	698	264	41 (-15)
car (Automobile)	11	28s	80	47.5s (-19.5s)	35295 (Automobile: 217 (first) 302 (all)*)	263 (Automobile: 23319 (first)*)	59 (Automobile: 10274 (first)*)	14 (+14s)
happiness	11	28s	179	20 (+8s)	1656	3988	2016	86 (-58s)
tree	11	28s	85	43s (-15s)	14692	695	262	40 (-12s)
book	10	30.5s	99	33.5s (-3s)	37675	252	54	12 (+18.5s)
cat	10	30.5s	59	70s (-39.5s)	5377	1758	833	68 (-37.5s)
air (Atmosphere_of_Earth)	9	34.5s	121	26 (+8.5s)	19046 (Atmosphere: 4902)	544 (Atmosphere: 1889)	189 (Atmosphere: 900)	30 (+4.5s)
clock	9	34.5s	98	35 (-0.5s)	3279	2533	1233	75 (-40.5s)
learning	9	34.5s	103	32 (+2.5s)	2040	3446	1721	82 (-47.5s)
mother	9	34.5s	133	24 (+10.5s)	27784	354	99	18 (+16.5s)
summer	9	34.5s	85	43s (-8.5s)	11563	876	361	46 (-11.5s)
television	9	34.5s	84	45.5s (-11s)	9603	1051	450	53 (-18.5s)

Table 3.4 part 2 of 3 (started on previous page and continues here and on next page).

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgarriff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
living	8	39.5s	105	29.5s (+10s)	1688	3937	1983	85 (-45.5s)
music	8	39.5s	91	38s (+1.5s)	15024	681	255	39 (+0.5s)
party	8	39.5s	87	40 (-0.5s)	52979	177	25	6 (+33.5s)
religion	8	39.5s	62	65.5s (-26s)	4798	1922	920	69 (-29.5s)
city	7	46.5s	52	79.5s (-33s)	21596	477	153	25 (+21.5s)
cloth (Clothing)	7	46.5s	95	36 (+10.5s)	2130 (Clothing: 1892)	3352 (Clothing: 3630)	1665 (Clothing: 1818)	81 (-34.5s)
elderness (Old age)	7	46.5s	60	68 (-21.5s)	X (Old age: N/A)	N/A (Old age: N/A)	N/A (Old age: N/A)	100s (-53.5s)
environment	7	46.5s	75	52 (-5.5s)	14403	717	276	42 (+4.5s)
father	7	46.5s	105	29.5s (+17s)	23216	436	132	22 (+24.5s)
freetime (Leisure)	7	46.5s	91	38s (+8.5s)	X (Leisure: 2866)	N/A (Leisure: 2781)	N/A (Leisure: 1361)	100s (-53.5s)
holiday	7	46.5s	91	38s (+8.5s)	9731	1031	438	51 (-4.5s)
light	7	46.5s	67	59.5s (-13s)	18853	553	194	31 (+15.5s)
pet	7	46.5s	64	63s (-16.5s)	1375	4543	2319	89 (-42.5s)
world	7	46.5s	106	28 (+18.5s)	59094	161	18	5 (+41.5s)
childhood	6	58s	76	50.5s (+7.5s)	2853	2789	1367	77 (-19s)
disease	6	58s	28	150s (-92s)	10736	940	389	49 (+9s)
emotion	6	58s	86	41 (+17s)	3418	2469	1196	74 (-16s)
experience	6	58s	66	61 (-3s)	22751	452	141	23 (+35s)
fun	6	58s	85	43s (+15s)	2976	2722	1332	76 (-18s)
ground	6	58s	74	53 (+5s)	21504	480	155	26 (+32s)
growing	6	58s	72	55 (+3s)	127 (first) 232 (all)*	33083 (first)*	14539 (first)*	96 (-38s)
hate (Hatred)	6	58s	30	144.5s (-86.5s)	236 (first) 568 (all)* (Hatred: 1076)	22083 (first)* (Hatred: 5299)	9758 (first)* (Hatred: 2703)	95 (-37s)
heart	6	58s	80	47.5s (+10.5s)	15242	672	249	37 (+21s)
paper	6	58s	32	133.5s (-75.5s)	23694	423	130	21 (+37s)
sea	6	58s	48	85 (-27s)	11430	887	364	48 (+10s)
shoe	6	58s	52	79.5s (-21.5s)	4746	1935	925	70 (-12s)
sport	6	58s	62	65.5s (-7.5s)	8698	1160	518	56 (+2s)
baby (Infant)	5	71.5s	73	54 (+17.5s)	11503 (Infant: 2547)	883 (Infant: 2981)	363 (Infant: 1463)	47 (+24.5s)
biology	5	71.5s	44	94.5s (-23s)	1029	5440	2783	90 (-18.5s)
eating	5	71.5s	69	58 (+13.5s)	503 (first) 1019 (all)*	13198 (first)*	5861 (first)*	94 (-22.5s)
flower	5	71.5s	47	87.5s (-16s)	7086	1366	629	60 (+11.5s)
forest	5	71.5s	59	70s (+1.5s)	6832	1419	658	61 (+10.5s)
god	5	71.5s	59	70s (+1.5s)	6297	1520	707	62 (+9.5s)
goodness	5	71.5s	70	57 (+14.5s)	1418	4447	2274	88 (-16.5s)
peace	5	71.5s	71	56 (+15.5s)	8847	1142	507	55 (+16.5s)
pen	5	71.5s	33	126.5s (-55s)	2374	3115	1541	80 (-8.5s)

Table 3.4 part 3 of 3 (started two pages earlier and continues here).

Concept (common noun)	Occurrences in word lists generated by students (n=103)		Sums of measures of importance (on scale 1–21, greater value indicating more important) given by students (n=103)		Occurrences in lemmatized word list (6318 words) of British National Corpus (* = concept not found in lemmatized word list and thus occurrences shown in non-lemmatized word list (words occurring over 5 times) for both just the highest-ranking matching word item (first) and sum of matching word items (all); X = concept not found in non-lemmatized word list; N/A = not available) (Kilgariff 1997)			
Concept generated by students (Nearest matching Wikipedia article title if not the same concept)	Occurrences	Ranking	Sums of measures of importance	Ranking (how many positions higher than ranking in column 3)	Occurrences	Ranking among all part-of-speech	Ranking among only common nouns	Ranking among only common nouns transformed into range 1–102 (how many positions higher than ranking in column 3)
philosophy	5	71.5s	52	79.5s (-8s)	3590	2387	1149	73 (-1.5s)
purpose	5	71.5s	84	45.5s (+26s)	15159	674	251	38 (+33.5s)
succeeding (Management)	5	71.5s	64	63s (+8.5s)	64 (first) 114 (all)* (Management: 21884)	50611 (first)* (Management: 470)	22087 (first)* (Management: 149)	97 (-25.5s)
war	5	71.5s	27	153s (-81.5s)	29722	331	89	17 (+54.5s)
young_(person) (Adolescence)	5	71.5s	30	144.5s (-73s)	47 (first) 62 (all)* (Adolescence: 408 (first) 440 (all)*)	60785 (first)* (Adolescence: 15312 (first)*)	26462 (first)* (Adolescence: 6794 (first)*)	98 (-26.5s)
bed	4	90.5s	44	94.5s (-4s)	17947	578	207	33 (+57.5s)
bread	4	90.5s	49	84 (+6.5s)	3780	2294	1100	72 (+18.5s)
chair	4	90.5s	10	418s (-327.5s)	9718	1034	440	52 (+38.5s)
dream_(sleeping)	4	90.5s	53	77 (+13.5s)	6050	1580	733	63 (+27.5s)
evolution	4	90.5s	37	107s (-16.5s)	2447	3059	1510	79 (+11.5s)
exam (Test_(assessment))	4	90.5s	30	144.5s (-54s)	1511 (Test: 15491)	4252 (Test: 161)	2163 (Test: 243)	87 (+3.5s)
future	4	90.5s	58	72 (+18.5s)	14174	730	282	43 (+47.5s)
goal_(to_achieve)	4	90.5s	64	63s (+27.5s)	10655	950	394	50 (+40.5s)
hospital	4	90.5s	38	104.5s (-14s)	16898	604	215	35 (+55.5s)
marriage	4	90.5s	51	82.5s (+8s)	8668	1164	521	57 (+33.5s)
nutriment (Diet_(nutrition))	4	90.5s	61	67 (+23.5s)	9 (first) 9 (all)* (Diet: 4201)	156638 (first)* (Diet: 2121)	69617 (first)* (Diet: 1017)	99 (-8.5s)
organism	4	90.5s	41	98.5s (-8s)	1809	3744	1897	84 (+6.5s)
oxygen	4	90.5s	79	49 (+41.5s)	1870	3662	1839	83 (+7.5s)
parent	4	90.5s	76	50.5s (+40s)	20060	515	176	28 (+62.5s)
people	4	90.5s	41	98.5s (-8s)	125430	80	3	2 (+88.5s)
phone (Telephone)	4	90.5s	47	87.5s (+3s)	7150 (Telephone: 7842)	1357 (Telephone: 1258)	621	59 (+31.5s)
physical_training (Physical_fitness)	4	90.5s	54	75.5s (+15.5s)	X (Fitness: 1499)	N/A (Fitness: 4278)	N/A (Fitness: 2178)	100s (-9.5s)
pleasure	4	90.5s	52	79.5s (+11s)	5853	1628	762	66 (+24.5s)
rain	4	90.5s	34	121.5s (-31s)	6012	1588	736	64 (+26.5s)
sadness	4	90.5s	32	133.5s (-43s)	769 (first) 795 (all)*	9743 (first)*	4283 (first)*	92 (-1.5s)
sister (Sibling)	4	90.5s	32	133.5s (-43s)	8592 (Sibling: 299 (first) 458 (all)*)	1180 (Sibling: 18796*)	531 (Sibling: 8325 (first)*)	58 (+32.5s)
teacher	4	90.5s	34	121.5s (-31s)	19744	523	180	29 (+61.5s)
time	4	90.5s	55	74 (+16.5s)	183427	53	1	1 (+89.5s)
travel	4	90.5s	67	59.5s (+31s)	4118	2158	1034	71 (+19.5s)

We used five just mentioned comparison tests in two different ways that focus either on actual frequency distributions or ranking values. We compared three rankings in respect to actual frequency distributions (shown in Table 3.4 in columns 2, 4 and 6) that these rankings represent by using two tests: sign test of paired samples and bootstrap version of Kolmogorov-Smirnov two-sample test. We compared three rankings in respect to ranking values (shown in Table 3.4 in columns 3, 5 and 9) that have been created based on these frequency distributions by using three tests: Goodman-Kruskal gamma statistic, Spearman's rank correlation coefficient rho and Kendall's rank correlation coefficient tau.

During comparisons in respect to three missing frequency values of British National Corpus, for each of concepts "elderness", "freetime" and "physical_training" we decided to use values of zero (i.e. for "elderness" 0; for "freetime" 0; and for "physical_training" 0).

Our computation relied on rankings shown in Table 3.4 in columns 3, 5 and 9, and among them rankings of columns 3 and 9 are already in a scale ranging from 1 to 102 and to enable better comparison we now transformed also rankings of column 5 into a scale ranging from 1 to 102. Thus in fact following comparisons do not compare original rankings concerning occurrences word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus but instead considering only 102 core concepts belonging to each of these three rankings and only when these rankings are observed in a shared scale of ranking values ranging from 1 to 102.

Sign test of paired samples relies on estimating the difference in medians between two distributions. *Kolmogorov-Smirnov two-sample test* relies estimating the supremum of set of distances between empirical distribution functions of two samples. Since traditional Kolmogorov-Smirnov two-sample test does not allow tie values (i.e. having shared ranking) we used bootstrap version of Kolmogorov-Smirnov two-sample test allowing tie values that relies on performing bootstraps based on Monte Carlo simulations and we used value 1000 as parameter of number of bootstraps to be performed since values of at least 500 or preferably 1000 have been suggested to reach suitable accuracy (Sekhon 2011).

Goodman-Kruskal gamma statistic, *Spearman's rank correlation coefficient rho* (ρ) and *Kendall's rank correlation coefficient tau* (τ) are non-parametric measures of statistical dependence between rankings of samples indicating the degree of correlation with values ranging from -1 (negative correlation) to 1 (positive correlation) so that value 0 represents absence of correlation.

We used each of five just mentioned comparison tests to check if a null hypothesis that corresponds each of these tests either becomes rejected or does not become rejected. Table 3.5 lists for each of the five tests a description about its null hypothesis supplied with notation that we used and we refer to this notation also in our further analysis.

Table 3.5. Five tests used to compare two samples in our research. A null hypothesis corresponding to each of five comparison tests is explained with notation and description.

Test comparing two samples	Null hypothesis	
<i>Name</i>	<i>Notation</i>	<i>Description</i>
sign test of paired samples	Hst	there is no difference in medians between two distributions represented by the two samples
bootstrap version of Kolgomorov-Smirnov two-sample test	Hks	both of the two samples represent the same distribution
Goodman-Kruskal gamma statistic	Hgk	gamma=0 thus meaning that there is absence of association between rankings of two samples
Spearman's rank correlation coefficient rho	Hsk	rho=0 thus meaning that there is absence of association between rankings of two samples
Kendall's rank correlation coefficient tau	Hkr	tau=0 thus meaning that there is absence of association between rankings of two samples

To facilitate identifying possible similarities between three frequency distributions of Table 3.4 we transformed frequency values into approximately same range of values thus forming scaled frequency distributions. We now next explain how this transformation was carried out. We empirically defined three weighting parameters that seemed to sufficiently successfully transform frequency values of each of three original distributions to three scaled distributions so that sign test of paired samples between each three pairs of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between each three pairs of these scaled frequency distributions is as small as possible.

Therefore we decided that scaled frequency distribution of occurrences in word lists has a weighting parameter 1 and scaled frequency distribution of sum of measures of importance a weighting parameter 0.085 and scaled frequency distribution of occurrences in British National Corpus a weighting parameter 0.00077. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution. Figure 3.1 shows three scaled frequency distributions, supplied with a curve $y = 328/x$ that is a prediction based on Zipf's law (Zipf 1935) which claims that in large samples of natural language the frequency of any word $f(z)$ is inversely proportional to its rank z based on the high-frequency list of all words (thus approximately $f(z) \sim 1/z$), and also parameter 328 in the formula of this curve $y = 328/x$ is motivated by thus minimizing difference in medians between the values of this curve and occurrences in word lists generated by students. We used these scaled frequency distributions in our further analysis including Figure 3.1, Table 3.6 and Figure 3.2.

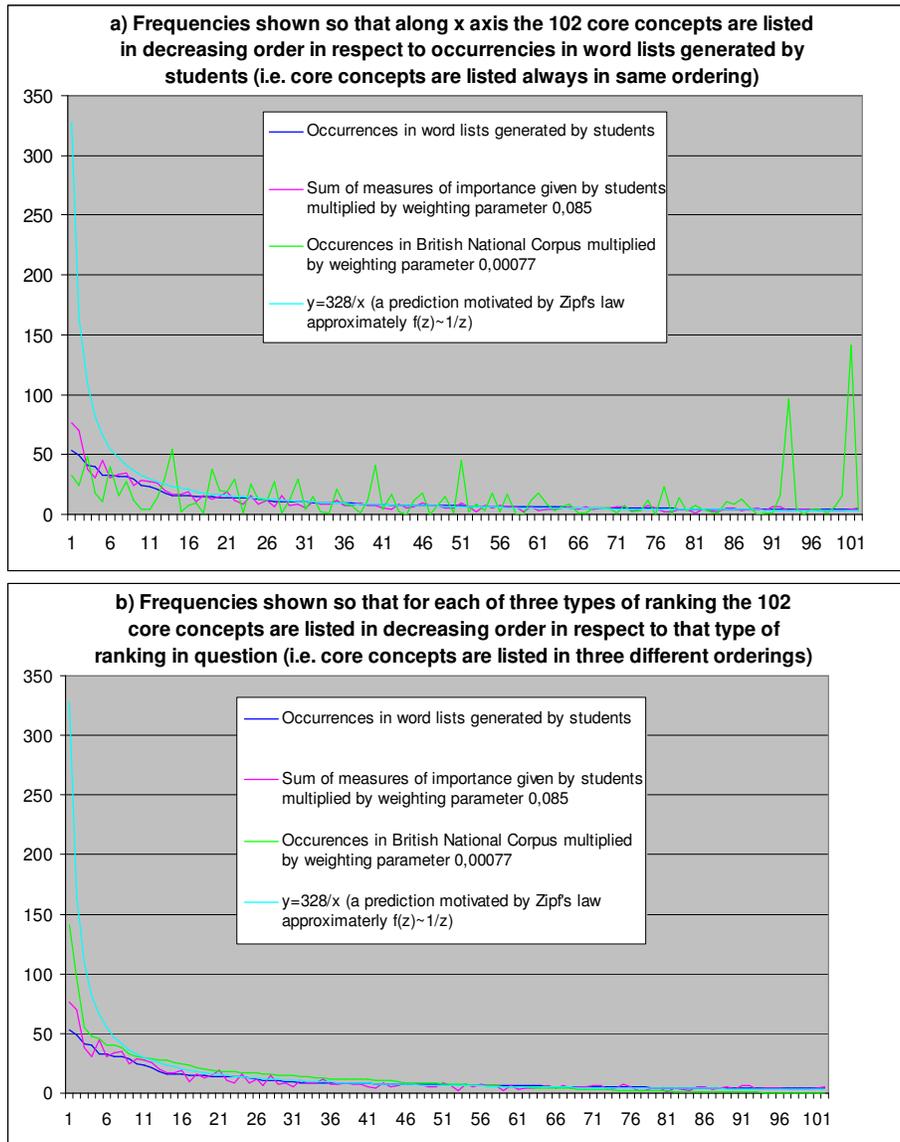


Figure 3.1. Scaled frequency distributions about rankings of occurrences in word lists of students, sum of measures of importance given by students and occurrences in British National Corpus so that core concepts are listed in same ordering thus frequencies not decreasing together (a) and in different ordering thus frequencies decreasing together (b). Ordering of core concepts in subfigure a is same as in first column of Table 3.4 (in decreasing order in respect to occurrences in word lists generated by students).

We carried out each of five comparison tests so that when comparing two samples we compared values that represented always the same concept (i.e. core concepts were always listed in same ordering in a similar way as shown in Figure 3.1 in subfigure a and not as in subfigure b, thus meaning in decreasing order in respect to occurrences in word lists generated by students). For each of five comparison tests Table 3.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between three rankings concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus (explained originally in publication [P9]). Figure 3.2 visualizes correlations between three ranking values

concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus.

Table 3.6. Degrees of dependency between three rankings concerning occurrences in word lists generated by students, sum of measures of importance given by students and lemmatized word lists of British National Corpus.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
Distribution A	Distribution B	Sign test of paired samples	Bootstrap version of Kolmogorov-Smirnov two-sample test	Goodman-Kruskal gamma statistic	Spearman's rank correlation coefficient rho	Kendall's rank correlation coefficient tau
Occurrences in word lists generated by students (scaled)	Sum of measures of importance given by students (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.03962 (null hypothesis Hks rejected)	gamma=0.7584478 (standard error 0.09718651); null hypothesis Hgk rejected (p=5.995204×10 ⁻¹⁵)	rho=0.8591361; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.7158213; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
Occurrences in word lists generated by students (scaled)	Occurrences in British National Corpus (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.00002393 (null hypothesis Hks rejected)	gamma=0.2785962 (standard error 0.1427654); null hypothesis not rejected (p=0.0510064)	rho=0.3661874; null hypothesis Hsr rejected (p=0.0001537)	tau=0.2637514; null hypothesis Hkr rejected (p=0.0001723)
Sum of measures of importance given by students (scaled)	Occurrences in British National Corpus (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.002647 (null hypothesis Hks rejected)	gamma=0.2468701 (standard error 0.1368832); null hypothesis Hgk not rejected (p=0.07130832)	rho=0.3576171; null hypothesis Hsr rejected (p=0.0002242)	tau=0.2459333; null hypothesis Hkr rejected (p=0.0002626)

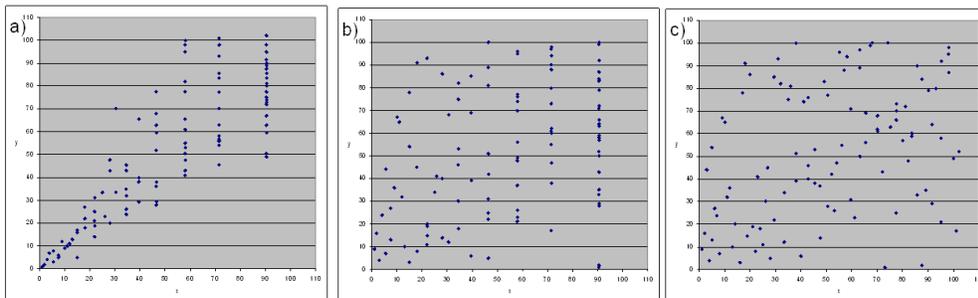


Figure 3.2. Visualization of three correlations: a) between ranking values of occurrences in word lists generated by students (x) (n=103) and ranking values of sum of measures of importance given by students (y) (n=103), b) ranking values of occurrences in word lists generated by students (x) (n=103) and ranking values of lemmatized word lists of British National Corpus (y), and c) ranking values of sum of measures of importance given by students (x) (n=103) and ranking values of lemmatized word lists of British National Corpus (y). To enable comparison, all ranking values are in scale ranging from 1 to 102 (thus differing from Table 3.4 the ranking values of sum of measures of importance given by students have now also been transformed into scale ranging from 1 to 102). Ordering of core concepts in all subfigures (a, b and c) is same as in first column of Table 3.4 (in decreasing order in respect to occurrences in word lists generated by students).

Based on comparison shown in Table 3.4, we have generated Table 3.7 showing the greatest and smallest ranking difference (distance of ranking positions) when comparing ranking based on sum of measures of importance (on scale 1–21, greater value indicating more important) given by each student for the words she generated to form her word list and ranking based on occurrences in word lists generated by students (explained originally in publication [P9]). To enable comparison, differing from Table

3.4 the ranking values of sum of measures of importance given by students have now also been transformed into scale ranging from 1 to 102.

Table 3.7. Some of the greatest and smallest ranking differences for concepts in respect to occurrences in word lists generated by students versus sum of measures of importance given by each student (n=103). Concepts having the greatest and smallest ranking difference when comparing ranking based on sum of measures of importance (on scale 1–21, greater value indicating more important) given by each student for the words she generated to form her word list and ranking based on occurrences in word lists generated by students. To enable comparison, differing from Table 3.4 the ranking values of sum of measure of importance given by students have now also been transformed into scale ranging from 1 to 102.

Some of the greatest ranking differences for concepts having higher ranking based on sum of measures of importance given by each student than based on occurrences in word lists generated by students		Some of the greatest ranking differences for concepts having lower ranking based on sum of measures of importance given by each student than based on occurrences in word lists generated by students		Some of the smallest ranking differences for concepts between ranking based on sum of measures of importance given by each student and based on occurrences in word lists generated by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
oxygen	41.5s	disease	-42s	family; friend; home	0
parent	40s	hate	-40s	hobby; sun	0s
travel	31s	cat	-39.5s	evolution	0.5s
goal_(to_achieve)	27.5s	paper	-37s	clock; party	-0.5s
purpose	26s	city	-31s	birth; human; nature	1
nutriment	23.5s	war	-29.5s	education	1s
future; world	18.5s	young_(person)	-26.5s	work	-1
baby; time	17.5s	religion	-26s	child; rain; teacher	-1s
emotion; father	17s	sea	-24s	food; forest; god; hospital; music	1.5s
		pen	-21.5s	joy	-2s
		elderness	-21.5s	learning; love; water	2.5s
				school	-2.5s

It appears that when contrasted with original frequency-based ranking of core concepts in word lists generated by students, the students on average gave higher sums of measures of importance to such concepts as “oxygen”, “parent”, “travel”, “goal_(to_achieve)” and “purpose”, and respectively lower sums of measures of importance to such concepts as “disease”, “hate”, “cat”, “paper”, “city”, “war” and “young_(person)”. The original frequency-based ranking of core concepts in word lists generated by students was followed closely by the levels of sums of measures of importance among such concepts as “family”, “friend”, “home”, “hobby” and “sun”. It is interesting that three concepts having the highest occurrences in word lists generated by students (“family”, “friend” and “work”) belong to those concepts having some of the smallest ranking differences between ranking based on sum of measures of importance and based on occurrences in word lists, so we think that possibly there can be some partially subconscious processes that assist humans to position certain

dominant concepts of everyday life often into same specific ranking positions even in varying contexts.

Similarly, based on comparison shown in Table 3.4, we have generated Table 3.8 showing the greatest and smallest ranking difference (distance of ranking positions) when comparing ranking based on occurrences in British National Corpus and ranking based on occurrences in word lists generated by students (explained originally in publication [P9]). It appears that when contrasted with original frequency-based ranking of core concepts in word lists generated by students, the frequency-based ranking in British National Corpus had a higher ranking for such concepts as “time”, “people”, “parent”, “teacher” and “bed”, and respectively a lower ranking to such concepts as “hobby”, “sorrow”, “joy”, “happiness” and “human”. The original frequency-based ranking of core concepts in word lists generated by students was followed closely by the frequency-based ranking in British National Corpus among such concepts as “music”, “work”, “philosophy”, “sadness” and “school”.

Table 3.8. Some of the greatest and smallest ranking differences for concepts in respect to occurrences in word lists generated by students (n=103) versus occurrences in British National Corpus. Concepts having the greatest and smallest ranking difference when comparing ranking based on occurrences in British National Corpus and ranking based on occurrences in word lists generated by students. Please note that concepts “elderness”, “freetime” and “physical_training” were not found either in lemmatized word list or non-lemmatized word list of British National Corpus occurring more than five times and thus a shared ranking value of 100s was given to these three concepts.

Some of the greatest ranking differences for concepts having higher ranking based on occurrences in British National Corpus than based on occurrences in word lists generated by students		Some of the greatest ranking differences for concepts having lower ranking based on occurrences in British National Corpus than based on occurrences in word lists generated by students		Some of the smallest ranking differences for concepts between ranking based on occurrences in British National Corpus and based on occurrences in word lists generated by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
time	+89.5s	hobby	-73s	music	+0.5s
people	+88.5s	sorrow	-71s	work	-1
parent	+62.5s	joy	-63s	philosophy; sadness; school	-1.5s
teacher	+61.5s	happiness	-58s	health; sport	+2s
bed	+57.5s	human	-57	home	+3
hospital	+55.5s	birth	-54	education	+3s
war	+54.5s	elderness; freetime	-53.5s	exam	+3.5s
future	+47.5s	learning	-47.5s	air; environment	+4.5s
world	+41.5s	living	-45.5s	holiday	-4.5s
goal_(to_achieve)	+40.5s	pet	-42.5s	water	-5.5s
				organism	+6.5s

It is interesting that four concepts related to topics in educational context (i.e. concepts “teacher”, “learning”, “school” and “education”) have different role in this comparison of rankings. Concept “teacher” has higher ranking in British National Corpus (suggested to emphasize vocabulary of adults), concept “learning” has a higher ranking in word lists generated by students (suggested to emphasize vocabulary of

young people), and for both concept “school” and concept “education” rankings are close in British National Corpus and word lists generated by students (suggested to have relatively neutral balancing emphasis on vocabularies of adults and young people). We think that already this example of three complementing perspectives towards concepts related to topics in educational context give support for our proposal of exploiting diverse alternative rankings of concepts and conceptual relationships to explore conceptual networks in pedagogically rewarding way thus addressing adaptively the learner’s personal needs.

Table 3.9 shows the highest-ranking conceptual relationships among the concept maps generated by the students in the experiment. Since the students did not specify linking direction for the relationships, each pair of concepts is shown in alphabetical order. The relationships are listed in descending order of occurrences in concept maps.

As explained above, we first identified 102 concepts, called *102 core concepts*, that at least four students mentioned in her generated list of concepts (shown in Table 3.4). We then formed a list containing all conceptual relationships that the students had defined between these 102 core concepts in concept maps drawn by students. In this publication we use notation conceptA↔conceptB (i.e. two concepts separated with so called currency sign (↔) having Unicode code U+00A4) to represent these relationships defined by students in concept maps since these relationship do not have any specified linking direction. We decided to take into further analysis a subset of this list so that it contains only such conceptual relationships that are mentioned by at least two students in concept maps. We expanded this subset to contain also those conceptual relationships—mentioned by at least two students in concept maps drawn by students—that had been defined between concept “brother” and 102 core concepts (this addition contained two relationships that are brother↔family and brother↔friend). Motivation for connecting concept “brother” to 102 core concepts is that we planned to compare drawn concept maps to hyperlink structure of the Wikipedia and in the Wikipedia both entry Sister and entry Brother are redirected to shared Wikipedia article Sibling and thus in the Wikipedia concept Sibling represents both concepts Brother and Sister.

Table 3.9. 145 core relationships that are in fact all those relationships between 102 core concepts, extended with concept Brother, that are mentioned by at least two students in concept maps drawn by students (n=103), shown in descending order of occurrences in concept maps. Since relationships do not have any specified linking direction, each pair of concepts is shown in alphabetical order (concept A and concept B).

Conceptual relationship (linking direction not specified)			Conceptual relationship (linking direction not specified)			Conceptual relationship (linking direction not specified)		
Concept A	Concept B	Occurrences	Concept A	Concept B	Occurrences	Concept A	Concept B	Occurrences
family	friend	15	death	war	3	environment	family	2
birth	death	13	dog	family	3	environment	nature	2
family	love	13	dog	pet	3	experience	work	2
friend	school	10	education	school	3	family	health	2
family	home	9	family	house	3	family	hobby	2
school	work	9	family	joy	3	family	money	2
animal	nature	8	family	work	3	family	pet	2
friend	love	8	food	health	3	family	phone	2
child	family	7	food	living	3	family	study	2
death	living	7	freetime	hobby	3	father	home	2
family	father	7	friend	party	3	food	television	2
family	living	7	ground	water	3	freetime	friend	2
joy	sorrow	7	happiness	love	3	freetime	television	2
family	mother	6	hobby	school	3	friend	living	2
father	mother	6	home	house	3	friend	pet	2
food	water	6	home	school	3	friend	study	2
friend	hobby	6	home	work	3	friend	work	2
money	work	6	living	religion	3	friend	young_(person)	2
birth	living	5	living	school	3	god	organism	2
education	work	5	living	water	3	ground	nature	2
living	nature	5	nature	sun	3	health	light	2
nature	plant	5	school	study	3	health	physical_training	2
plant	tree	5	air	ground	2	heart	love	2
study	work	5	animal	environment	2	hobby	work	2
air	water	4	animal	god	2	holiday	party	2
animal	dog	4	animal	tree	2	holiday	work	2
cat	dog	4	birth	child	2	home	mother	2
computer	television	4	birth	family	2	house	work	2
death	disease	4	birth	growing	2	joy	living	2
death	health	4	birth	human	2	joy	love	2
family	happiness	4	birth	nature	2	learning	love	2
family	human	4	book	school	2	living	music	2
friend	happiness	4	brother	family	2	living	organism	2
friend	human	4	brother	friend	2	living	peace	2
friend	joy	4	car	family	2	living	purpose	2
human	living	4	car	house	2	living	sorrow	2
human	love	4	chair	house	2	living	sun	2
human	nature	4	child	hospital	2	living	travel	2
living	love	4	child	human	2	love	mother	2
living	work	4	clock	computer	2	love	nature	2
nature	water	4	clock	school	2	love	parent	2
animal	family	3	cloth	shoe	2	nature	tree	2
animal	food	3	computer	freetime	2	nutriment	water	2
animal	human	3	death	nature	2	oxygen	water	2
biology	nature	3	disease	health	2	school	teacher	2
birth	health	3	dream_(sleeping)	health	2	sea	water	2
death	elderness	3	education	living	2	summer	sun	2
death	human	3	elderness	health	2			
death	sorrow	3	emotion	love	2			
(the list continues in column 4)			(the list continues in column 7)					

Finally, we had managed to form a collection of altogether 145 conceptual relationships, called *145 core relationships*, aiming to represent knowledge structures of the students between 102 core concepts extended with concept “brother” (explained originally in publication [P9]). It turned out that in these 145 core relationships only 75 distinct concepts of 102 core concept are used (75 of 102 concepts if word “brother” can be seen representing word “sister” since it appears that concept “sister” is not inherently among those 75 distinct concepts although concept “sister” belongs to 102 core concepts). We think that relationships identified for concept “brother” can sufficiently represent relationships identified for concept “sister” when comparing concept maps and hyperlink structure of the Wikipedia especially when considering a broader conceptual context of term sibling (since, as just mentioned, in the Wikipedia concept Sibling represents both concepts Brother and Sister). Table 3.9 shows a listing of all 145 core relationships in descending order of occurrences in concept maps generated by teenaged students and since these relationships do not have any specified linking direction, each pair of concepts are shown in alphabetical order.

Figure 3.3 shows all 145 core relationships. Please note that in Figure 3.3 and in all other resembling figures of this publication the location of a concept in respect to other concepts and length of arcs or arrows connecting them does not have any specific indication about closeness or relatedness of these concepts. This means that concepts are placed to their location just based on human intuition with an aim to keep visualization of network of concepts as compact and clear as possible so that new connecting lines could be easily drawn from one concept to another concept so that other lines can still be easily distinguished from them.

In Figure 3.3 linking direction of a relationship between a pair of concepts was not specified in concept maps and thus only connecting lines are shown instead of arrows. Figure shows 73 concepts plus an additional concept brother. Concepts that do not have exactly same phrasing in the nearest corresponding article titles in the Wikipedia are supplied with an asterisk (*) and in addition concept brother is written in italics due to representing also related terms sister and Sibling. To facilitate comparison of this figure with analysis presented later in this dissertation two specific notations are made to this figure: concepts that are not mentioned in hyperlinks of the Wikipedia connecting 102 core concepts are written with purple font (see explanation in text just before Table 5.4) and concepts that have been unreachable in surfing experiment inside “hyperlink network of 55 concepts” starting from concept Human are written with turquoise font (see Table 5.19).

Figure 3.4 shows 41 highest-ranking hyperlinks of 145 core relationships (based on Table 3.9) so that greater width of the connecting lines indicates higher number of occurrences in concept maps drawn by students. Thus Figure 3.4 can be seen to show a highest-ranking subsection of the hyperlinks of Figure 3.3 and even supplied with line width indicating hierarchy among these hyperlinks in respect to number of occurrences in concept maps.

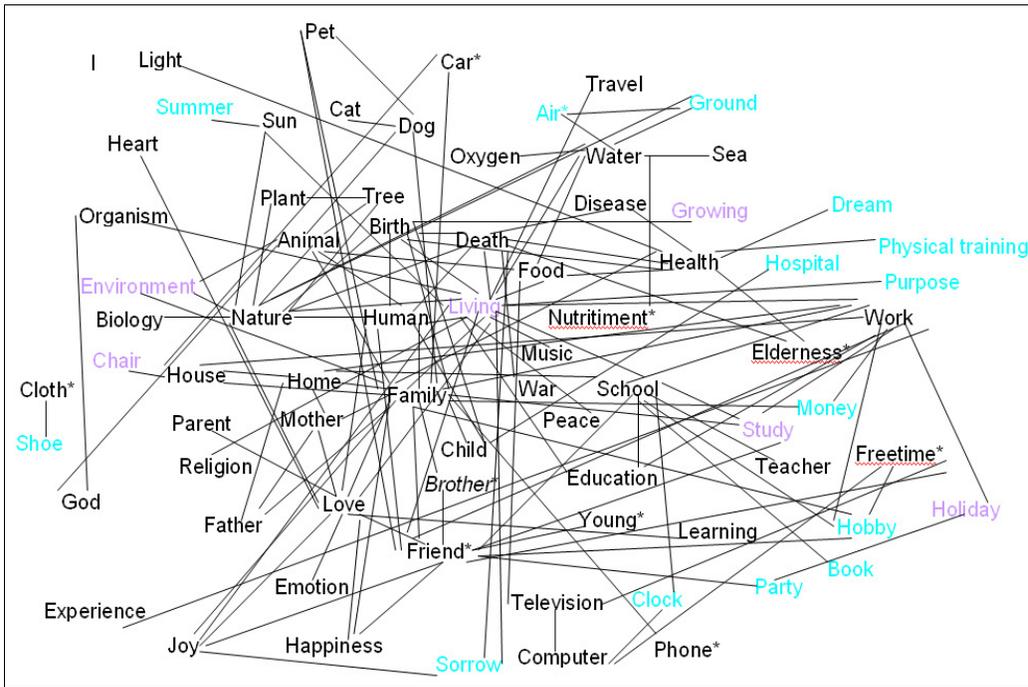


Figure 3.3. Visualization of all 145 core relationships, i.e. those relationships between 102 core concepts extended with concept “brother” that are mentioned by at least two students in concept maps drawn by students (n=103), listed in Table 3.9.

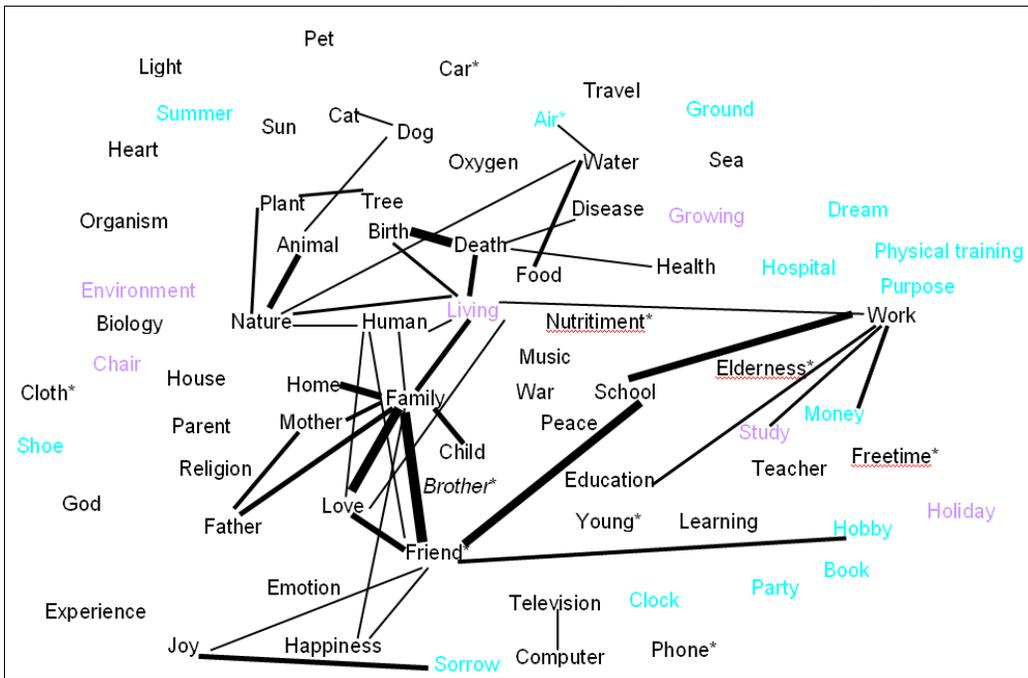


Figure 3.4. Visualization of 41 highest-ranking hyperlinks of 145 core relationships (based on Table 3.9) so that greater width of the connecting lines indicates higher number of occurrences in concept maps drawn by students (n=103).

PART II. Collaborative building of link-based knowledge representations in learning

Chapter 4. Addressing complementing personal strengths in collaborative learning platform

In publication [P1] we proposed an *educational framework* (collaborative learning platform) and computational methodology for collaborative learning. In publication [P1] we define a new way to support creative collaborative work of building knowledge structures and coordination of collaborative activities to gain mutually agreed solutions in web environment based *Competing Values Framework* model that is motivated by long empirical studies carried out in organizational studies ((Quinn & Rohrbaugh 1983); (Belasen & Frank 2008)).

We now here first explain basic idea and motivation about Competing Values Framework model and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P1]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P1]. Figure 4.1 illustrates the main idea of the method proposed in publication [P1].

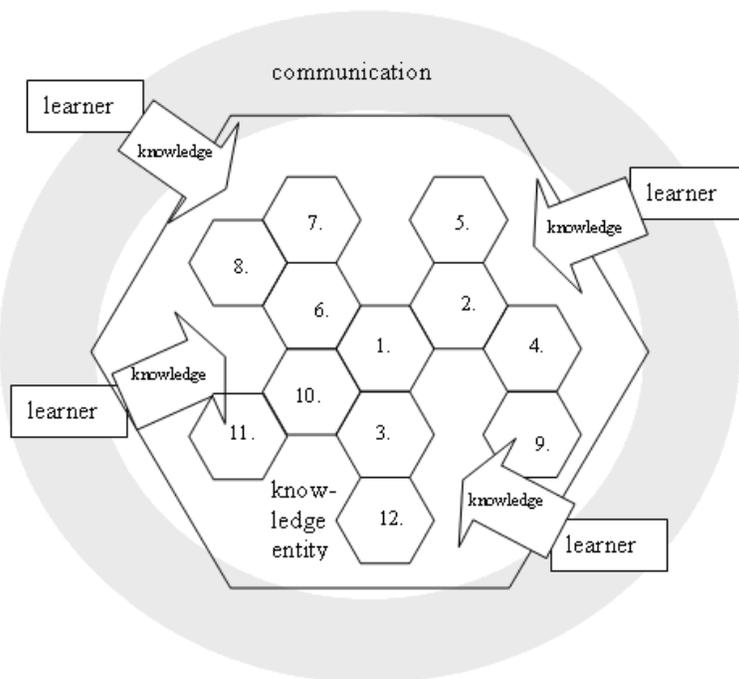


Figure 4.1. Main idea of the method proposed in publication [P1] for collaborative learning platform.

In Figure 4.1 the linked hexagons together represent a collectively generated and gradually built concept map by collaborating learners. Each hexagon represents a concept added or edited by one of the collaborators (corresponding to a node in concept map) and a shared edge between two hexagons indicate defined relationship between concepts (corresponding to an arc in concept map). The numbers indicate the order in which the concepts have been added to the concept map. Along collaborative knowledge construction process communication is carried out between all collaborators to agree about actions to be taken.

We do not know any previous research trying to apply Competing Values Framework in to educational setting in the proposed way. Please note that in the following text our educational framework (collaborative learning platform) will be referred to as a *platform* even if we consider it essentially to represent a framework since we want to avoid confusion with the model of Competing Values Framework. In publication [P1] we actively refer to our educational framework (collaborative learning platform) with terms collaborative ideation scheme and collaborative ideation platform.

4.1. Requirements for a collaborative learning platform

We suggest that productive computer-assisted collaboration can be based on even rather modest set of shared tools. Especially in educational domain, this ensures that complexity does not hinder intuitive usability of tools (Cheon & Grant 2008). As explained in publication [P1] some aspects that we consider essential for a collaborative learning platform supporting computer-assisted learning include formation of a group, identification of a collaborator role for each participant, sharing responsibilities according to person's collaborator role and enabling rich textual dialogue with visualization. We considered that shared concept maps can be valuable for synthesizing and distributing collaborative work.

In publication [P1] we suggest building a system that monitors collaboration activities and if personal responsibilities of collaborators do not become fulfilled, the system should provide guidance messages to restore desired activity patterns. We suggest a methodology for collaborative learning platform in the context of supporting learning of conceptual structures collaboratively. Collaborating learners are expected to expand their conceptualization while they relatively intuitively and associatively communicate to chain concepts in dialogue and with graphical notation based on their complementing initiatives.

As explained in publication [P1], we propose that a collaborative learning platform should provide functions to accomplish at least following tasks performed by collaborators: suggesting new ideas accompanied with explanations, referring to earlier suggested ideas, commenting on others' ideas, sending coordination messages for selected recipients, synthesizing ideas into compact graphical notation and distributing topics for reconsideration from graphical notation.

In publication [P1] we propose that with the collaborative learning platform a group of collaborators participate together in ideation that can be considered as cumulative

generation, reformulation and iteration of ideas and conceptualizations in a process having features of brainstorming. According to her intuition, each collaborator should publish through two separate textual dialogue channels, the first channel containing actual ideas and the second channel more general messages about timetables, tasks to be done and division of the work. Besides writing, each collaborator should be able to also build and edit a shared *concept map* on the drawing area. All additions and edits, both written and graphical, are submitted to a relational MySQL database running in web server and become then instantly shared by others online via web user interface. Aim of the collaboration is to explore word associations through dialogue and to synthesize newly learned conceptual structures to a mutually agreed concept map.

In publication [P1] we suggest that for all actions performed with the collaborative learning platform are gathered as a *log* into a database, each action associated with a timestamp and contributor's name, and providing a possibility to revert back to earlier states in the ideation. Reviewing earlier actions can be supplemented with a possibility to review filtered sets of previous actions using some criteria, like type of action or contributor. If a learner wants to comment or further elaborate something previously proposed item (idea, message, edit of concept map etc.), it should be referenced by its unique time stamp and contributor's name. This enables the system to track relations between individual contributions and how synthesis is drawn or how topics are distributed for reconsideration.

If a collaborator needs some *stimulation* for producing new ideas she can request a list of concepts that are related to a currently discussed concept which are then retrieved from the Wikipedia online encyclopedia by pressing button "Suggest inlinks" or button "Suggest outlinks". The system retrieves a *Wikipedia article* corresponding to currently discussed concept and identifies articles that are connected to it by an arriving or departing hyperlink and considers their titles as needed concepts. Suitable concepts from the retrieved list can be then added directly to the shared concept map by pressing button "Selected to map".

We have implemented the proposed collaborative learning platform in a web-based *prototype application* with Java. Figure 4.2 (originally published as Figure 2 in publication [P1]) shows an overview of the user interface. We have carried out user tests with volunteers of varied background to confirm the expected benefits of the methodology of the suggested collaborative learning platform. These user tests – based on a collection of statistical data that represents five persons for each of four of collaborator roles of Competing Values Framework, together twenty persons (n=20) – have indicated that the proposed collaborative learning platform can support collaborative ideation and learning conceptual structures on pretty easy level (more results explained in Subchapter 4.3). We suggest that using the collaborative learning platform online can enable reducing constraints of location and synchronization of timetables of collaborators but on the other hand we also suggest using the collaborative learning platform offline and possibly together at same location to address social needs.

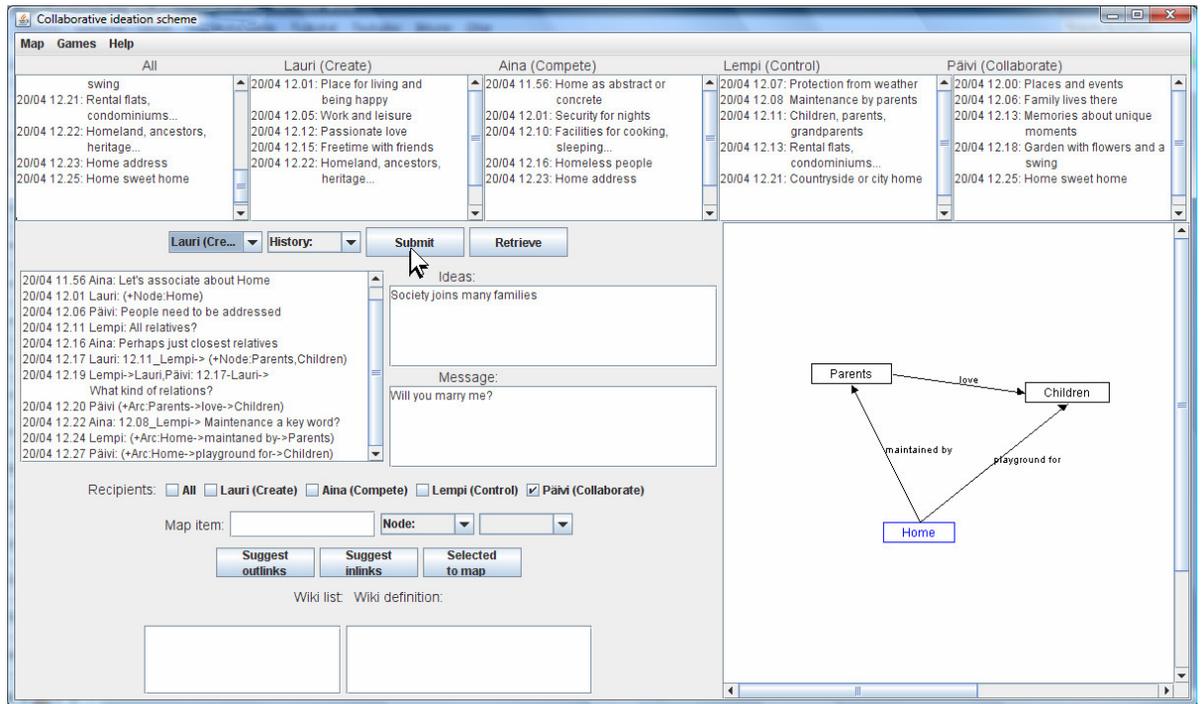


Figure 4.2 (originally published as Figure 2 in publication [P1]). User interface of the prototype proposed in publication [P1].

4.2. Supporting distinctive collaborative roles with Competing Values Framework

Various working strategies (Suthers 2005) and a variety of time scales and activity frequency distributions (Stahl 2006) can suit for *collaborative knowledge construction*. We propose that alternative models can be used to address complementing roles of collaborators taking advantage of personal specific skills supporting an individual to focus on certain type of activities in collaboration. Anyway, among currently actively studied models we think that Competing Values Framework is promising and in publication [P1] we proposed using this model to distribute tasks and to support that these tasks are carried out along a typical activity belonging to each role and task.

Competing Values Framework (CVF) was originally developed from research on the major indicator of effective organizations by asking workers to assess the relative similarity of pairs of effectiveness measures (Quinn & Rohrbaugh 1983) leading to a model with two major dimensions that deal with internal-external orientation and flexibility-stability orientation, and each quadrant associated with certain tasks. *Innovation Genome Model* (IGM) is a more recent variation of Competing Values Framework developed for understanding specifically the different types of innovations that exist in organizations (DeGraff & Quinn 2006). As illustrated with Figure 4.3 (originally published as Figure 1 in publication [P1]), four quadrants of Competing Values Framework and Innovation Genome Model can be described with following complementing *collaborator roles*: innovator-broker (create), producer-director (compete), coordinator-monitor (control) and facilitator-mentor (collaborate). These

roles, in same listing order, can be associated with following management models and tasks: open system model (flexibility and readiness), rational goal model (planning and goal-setting), internal process model (information management and communication) and human relations model (cohesion and morale).

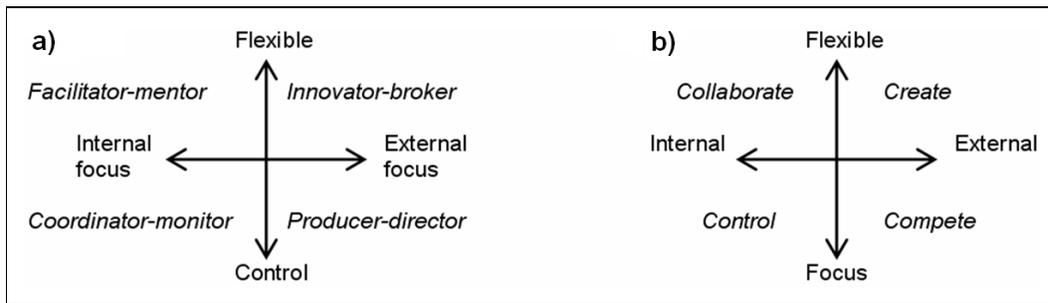


Figure 4.3 (originally published as Figure 1 in publication [P1]). Abstract orientations of organizational management according to the Competing Values Framework (a) and the Innovation Genome Model (b). Both models show two dimensions of qualities for collaboration and corresponding quadrants that represent roles based on dominant characteristics of collaborators.

Since it appears that Innovation Genome Model is not very actively used terminology in research literature so far and we consider it very closely resembling popular Competing Values Framework model, we have decided it appropriate to convert our results about Innovation Genome Model discussed in publication [P1] to be discussed in this dissertation in respect to Competing Values Framework model. Please note also that somewhat confusingly one of the collaborator roles, Facilitator-mentor (collaborate), has naming that includes term collaborate since it is expected to facilitate and mentor collaboration work of the group but naturally all four collaborator roles participate in collaboration in complementing ways addressing their own strengths.

It has been shown that both individuals and organizations can be classified to correspond one of four collaborator roles based on their dominant characteristics and taking into account all of them enables a balanced collaboration workflow ((DeGraff & Quinn 2006); (Buenger et al. 1996); (Gregory et al. 2009); (Yang & Shao 1996)). Despite many alternative attractive models (Cameron et al. 2006), we decided to rely on Competing Values Framework model since it is widely respected and adopted analysis tools (Belasen & Frank 2008) and earlier experimental data enables rich comparative analysis (Kalliath et al. 1999). In publication [P1] we propose using theoretical foundation based on Competing Values Framework model for defining collaborative requirements for computer-assisted collaborative learning platform. We think that this model enables to develop simple and transparent system suitable for practical learning scenarios that can be experimentally evaluated.

4.3. Defining activity patterns and their frequencies to support collaborative roles

In publication [1] we have listed some common tasks for the suggested collaborative learning platform that are associated with each quadrant of Competing Values Framework model (see Table 4.1 (modified version of Table 1 originally published in publication [P1])). We think that tracking these tasks can enable generating automatically appropriate personal support for activities of each collaborator role. Our aim was to identify and describe some activities typically for using user interface of a computer application.

Table 4.1 (modified version of Table 1 originally published in publication [P1]). Suggestion of some typical tasks for collaborator roles based on Competing Values Framework (CVF).

<i>Innovator-broker role (create)</i>	<i>Producer-director role (compete)</i>	<i>Coordinator-monitor role (control)</i>	<i>Facilitator-mentor role (collaborate)</i>
<ul style="list-style-type: none"> - submits a lot of ideas - explores accordance of ideas and concept map - adds nodes to concept map - questions constraints 	<ul style="list-style-type: none"> - sets goals for ideation - maintains holistic efficiency - comments concept map - aims at logic flow 	<ul style="list-style-type: none"> - comments ideas - synthesizes ideas to map - edits concept map - references to ideas 	<ul style="list-style-type: none"> - aims at agreement by personal messaging - distributes topics from concept map for reconsideration - adds arcs to concept map - references to concept map

By analysing lists of typical activities identified for each collaborator role ((Quinn & Rohrbaugh 1983); (DeGraff & Quinn 2006); (Carte et al. 2006); (Pounder 2000); (Noypayak & Speece 1998)) we heuristically proposed in publication [P1] coarse frequency distributions for some activities performed with a collaborative learning platform. As we emphasized in publication [P1], the proposed coarse relative activity frequencies tried to loosely indicate how some activities are expected to be performed more by certain collaborator roles than by others. We suggested that empirical testing is needed to acquire actual frequency values. After publication of the publication [P1] we carried out an empirical experiment with 66 students having ages in range 15–18 years and representing four roles of Competing Values Framework and we evaluated their collaborative concept map construction process in small groups. For each student we identified which of four major collaborator roles (shown in Table 4.1 (modified version of Table 1 published in publication [P1])) he represents by a questionnaire. Among these 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate).

Without revealing in advance what is the purpose of the questionnaire we asked the student to fill in a competing values self-assessment questionnaire that is adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23–24)) (shown in Appendix T) and among the six sets of four questions corresponding to each four major collaborator roles that role which received the highest number of points was selected as the role of the student for collaborative concept map construction process in small groups. In the questionnaire questions 1–6 concern having characteristics of innovator-broker role, then questions 7–

12 producer-director role, next questions 13–18 coordinator-monitor role and finally then questions 19–24 facilitator-mentor role. We recorded a log of activities for students participating in collaborative concept map construction process in small groups. Based on the number of occurrences of twelve different types of activities we identified for the individual members of groups, we gained a collection of statistical data that represents five persons for each of four collaborator roles of Competing Values Framework, together twenty persons ($n=20$), shown in Table 4.2. Even if sample sizes remain small we think that this experiment can offer useful results. Please note here that we had to exclude 46 persons from original 66 persons of the experiment due to challenges of forming suitable groupings.

We decided to use *one-way analysis of variance (ANOVA)* to test for differences in occurrences of twelve activities among four roles of Competing Values Framework based on values shown in Table 4.2 so that we considered so called F value representing the ratio of variance between groups to variance within groups. Before carrying out analysis of variance, we tested data for homogeneity of variance with Fligner-Killeen test of homogeneity of variance that has been considered robust to data that is not normally distributed and this test has a null hypothesis H_{fk} that variances for all samples are equal. It turned out that Fligner-Killeen test of homogeneity of variance for occurrences of twelve activities among four roles of Competing Values Framework, when considering occurrences by each role as samples for an activity, produced p-values in range from 0.09226 to 0.9787 thus meaning that the null hypothesis H_{fk} was not rejected at $p<0.05$.

According to one-way ANOVA, occurrences did not differ significantly among four roles in respect to following activities (since F values remained below critical value of 3.239 that corresponds to degrees of freedom $df_{within_groups}=20-4=16$ and $df_{between_groups}=4-1=3$ at $p<0.05$):

- submitting ideas ($F(3,16)=2.764$; $p = 0.0759$),
- adding nodes to concept map ($F(3,16)=1.565$; $p=0.237$),
- adding arcs to concept map ($F(3,16)=0.785$; $p=0.519$),
- making references to ideas ($F(3,16)=0.187$; $P=0.904$),
- making references to concept map ($F(3,16)=0.591$; $p=0.63$),
- commenting concept map ($F(3,16)=1.087$; $p=0.383$),
- synthesizing ideas to concept map ($F(3,16)=1.064$; $p=0.392$),
- distributing topics from concept map for reconsideration ($F(3,16)=0.349$; $p=0.79$),
- exploring accordance of ideas and concept map ($F(3,16)=0.69$; $p=0.572$) and
- requesting stimulation for creative thinking ($F(3,16)=0.139$; $p=0.935$).

On the other hand according to one-way ANOVA, occurrences differed significantly among four roles in respect to following two activities (since F values exceeded critical value of 3.239 that corresponds to degrees of freedom $df_{within_groups}=20-4=16$ and $df_{between_groups}=4-1=3$ at $p<0.05$):

- commenting ideas ($F(3,16)=6.39$; $p=0.00472$) and
- sending coordination messages ($F(3,16)=5.967$; $p=0.00626$).

Table 4.2. Occurrences of twelve activities among four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20).

<i>Members belonging to groups of Competing Values Framework collaborator roles</i>	<i>Submits ideas</i>	<i>Adds nodes to concept map</i>	<i>Adds arcs to concept map</i>	<i>Makes references to ideas</i>	<i>Makes references to concept map</i>	<i>Comments ideas</i>	<i>Comments concept map</i>	<i>Sends coordination messages</i>	<i>Synthesizes ideas to concept map</i>	<i>Distributes topics from concept map for reconsideration</i>	<i>Explores accordance of ideas and concept map</i>	<i>Requests stimulation for creative thinking</i>
<i>Innovator-broker (create)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
IB 1	4	6	9	3	1	2	1	5	15	0	0	1
IB 2	6	5	5	2	2	2	4	11	10	0	1	4
IB 3	8	7	8	1	3	3	3	12	15	0	2	1
IB 4	4	4	5	0	2	1	3	6	9	0	2	2
IB 5	7	9	13	5	4	2	4	8	22	2	1	2
Average	5.8	6.2	8	2.2	2.4	2	3	8.4	14.2	0.4	1.2	2
Variance	3.2	3.7	11	3.7	1.3	0.5	1.5	9.3	26.7	0.8	0.7	1.5
Proportion of group	0.187097	0.22963	0.232558	0.314286	0.181818	0.119048	0.176471	0.168	0.23127	0.222222	0.103448	0.277778
<i>Producer-director (compete)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
PD 1	3	4	4	2	2	2	4	5	8	0	0	1
PD 2	5	10	13	0	6	2	7	11	23	2	3	3
PD 3	5	6	5	5	3	5	4	12	11	0	23	2
PD 4	6	7	8	0	4	4	6	13	15	0	2	0
PD 5	8	3	5	2	2	4	4	14	8	1	1	3
Average	5.4	6	7	1.8	3.4	3.4	5	11	13	0.6	5.8	1.8
Variance	3.3	7.5	13.5	4.2	2.8	1.8	2	12.5	39.5	0.8	93.7	1.7
Proportion of group	0.174194	0.222222	0.203488	0.257143	0.257576	0.202381	0.294118	0.22	0.211726	0.333333	0.5	0.25
<i>Coordinator-monitor (control)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
CM 1	2	6	6	1	1	6	3	10	12	0	1	0
CM 2	14	7	7	2	1	8	1	25	14	1	2	6
CM 3	18	6	16	1	8	3	8	21	22	1	1	0
CM 4	7	9	12	2	6	9	8	17	21	0	0	0
CM 5	13	4	7	1	4	4	4	17	11	1	7	1
Average	10.8	6.4	9.6	1.4	4	6	4.8	18	16	0.6	2.2	1.4
Variance	39.7	3.3	18.3	0.3	9.5	6.5	9.7	31	26.5	0.3	7.7	6.8
Proportion of group	0.348387	0.237037	0.27907	0.2	0.30303	0.357143	0.282353	0.36	0.260586	0.333333	0.189655	0.194444
<i>Facilitator-mentor (collaborate)</i>	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences	Occurrences
FM 1	8	10	8	5	3	4	5	12	18	0	1	2
FM 2	11	7	9	1	2	7	2	12	16	0	0	1
FM 3	9	8	11	2	5	6	5	15	19	0	9	4
FM 4	10	9	12	0	3	4	4	13	21	0	2	2
FM 5	7	8	9	0	4	6	5	11	17	1	0	1
Average	9	8.4	9.8	1.6	3.4	5.4	4.2	12.6	18.2	0.2	2.4	2
Variance	2.5	1.3	2.7	4.3	1.3	1.8	1.7	2.3	3.7	0.2	14.3	1.5
Proportion of group	0.290323	0.311111	0.284884	0.228571	0.257576	0.321429	0.247059	0.252	0.296417	0.111111	0.206897	0.277778
<i>All groups</i>												
Sum of occurrences	155	135	172	35	66	84	85	250	307	9	58	36
F values of ANOVA	2.764	1.565	0.7853	0.1867	0.5906	6.390	1.087	5.967	1.064	0.3492	0.6896	0.1391

Thus these two activities both required a *Tukey post-hoc test*. Concerning activity of commenting ideas, Tukey post-hoc comparison of four roles was carried out and it indicated that role of coordinator-monitor (mean 6.0) had significantly higher occurrences than role of innovator-broker (mean 2.0) at $p=0.0064730$; and it indicated also that role of facilitator-mentor (mean 5.4) had significantly higher occurrences than role of innovator-broker (mean 2.0) at $p=0.0210340$; whereas other Tukey post-hoc comparisons were not statistically significant at $p<0.05$.

Concerning activity of sending coordination messages, Tukey post-hoc comparison of four roles was carried out and it indicated that role of coordinator-monitor (mean value 18.0) had significantly higher occurrences than role of innovator-broker (mean value 8.4) at $p=0.0042674$; and it indicated also that role of coordinator-monitor (mean value 18.0) had significantly higher occurrences than role of producer-director (mean value 11.0) at $p=0.0395745$; whereas other Tukey post-hoc comparisons were not statistically significant at $p<0.05$.

These just described results of one-way ANOVA should be considered with some uncertainty, for example due to limited sample sizes, but they offer some insight for modeling activity patterns of four different roles of Competing Values Framework.

Based on Table 4.2 we still wanted to present in compact form the frequency distributions for collaborative activities in respect to each four major collaborator role in Table 4.3 (modified version of Table 2 originally published in publication [P1]). These new empirical values differ from the previous values heuristically suggested in publication [P1] and we suggest that these new frequency distributions should be given priority when implementing an automated monitoring and guidance system for creative collaborative work as suggested in publication [P1]. The more general listing of activities in Table 4.1 (modified version of Table 1 originally published in publication [P1]) is slightly reformulated in Table 4.3 (modified version of Table 2 originally published in publication [P1]) to suit more specific context of the collaborative learning platform implemented with prototype.

As already mentioned, in our proposed method each collaborator is asked to fill in a self-assessment questionnaire adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23–24)) to identify her dominant collaborator role in respect to Competing Values Framework. However sometimes it can turn out that the persons available for collaboration do not have a balanced distribution of all four collaborator roles. To address also these situations, we suggest that based on the set of questions of questionnaire receiving the highest number of points the most matching collaborator roles are given to participants but an additional requirement is to ensure that each of the four roles are taken by someone and with less than four persons requires a person being responsible for several roles. Thus sometimes a person needs to take a collaborator role that is not the most dominant for her but anyway she is among the available persons the person who has received the highest number of points in respect to set of questions concerning that role.

Table 4.3 (modified version of Table 2 originally published in publication [P1]). Some empirically gained activity frequencies for 12 activities among four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20). For each activity the highest activity frequency is supplied with an asterisk (*) and if there are more than one activity sharing this highest value all of them are supplied with a double asterisk (**). For example, in a collaborative ideation session a person having Innovator-broker role is expected to contribute about 18.7 percent of all activities dealing with “submitting ideas”, Producer-director about 17.4 percent, Coordinator-monitor about 34.8 percent and Facilitator-mentor about 29.0 percent respectively. These empirically gained values can be contrasted with heuristically approximated values that we published in publication [P1] and can be seen in Appendix R.

<i>Type of activity</i>	<i>Innovator-broker role (create)</i>	<i>Producer-director role (compete)</i>	<i>Coordinator-monitor role (control)</i>	<i>Facilitator-mentor role (collaborate)</i>	Σ
Submits ideas	0.187096774	0.174193548	0.348387097*	0.290322581	1.000
Adds nodes to concept map	0.22962963	0.222222222	0.237037037	0.311111111*	1.000
Adds arcs to concept map	0.23255814	0.203488372	0.279069767	0.284883721*	1.000
Makes references to ideas	0.314285714*	0.257142857	0.200000000	0.228571429	1.000
Makes references to concept map	0.181818182	0.257575758	0.303030303*	0.257575758	1.000
Comments ideas	0.119047619	0.202380952	0.357142857*	0.321428571	1.000
Comments concept map	0.176470588	0.294117647*	0.282352941	0.247058824	1.000
Sends coordination messages	0.168000000	0.220000000	0.360000000*	0.252000000	1.000
Synthesizes ideas to concept map	0.231270358	0.211726384	0.260586319	0.296416938*	1.000
Distributes topics from concept map for reconsideration	0.222222222	0.333333333**	0.333333333**	0.111111111	1.000
Explores accordance of ideas and concept map	0.103448276	0.500000000*	0.189655172	0.206896552	1.000
Requests stimulation for creative thinking	0.277777778**	0.250000000	0.194444444	0.277777778**	1.000

We think that each collaborating group benefits from having a freedom to decide itself about practical guidelines for practically performing their creative work together, including sharing responsibilities and agreeing on timing patterns. We think that the complementing efforts from each collaborator should be let to be generated spontaneously without any strict predefined constraints. Anyway, to support exploitation of the specific complementing strengths of each collaborator we propose that a collaborative learning platform monitors activity patterns of each collaborator role and if they differ sufficiently from the expected activity profiles the system asks the representatives of this role to adjust that activity to follow the expected profile. This practice aims to ensure most productive collaboration. For example, the system can measure activity distribution during preceding 5 minutes and if the measured activity of a collaborator differs with a sufficient number of percents from her expected activity profile she will be informed and asked to adjust her activity to more closely match expected activity profile. If the situation does not change after three reminders the system sends a notice also to other collaborators. In publication [P1] we suggested that

if activity departs from expected activity profile over 20 percent the system intervenes but based on later experiments we suggest giving tolerance for variation until the activity frequencies reach a new maximum or a minimum value, as discussed later in this Chapter 4.

It needs to be emphasized that we think that useful activity frequency distributions should be measured for also many other types of activities than those shown in Table 4.3 (modified version of Table 2 originally published in publication [P1]). We think that with increasing number of parallel activity measures it could be possible to offer better guidance for each type of collaborative complementing efforts that can be generated by specific strengths belonging to representatives of each possible collaborator role of Competing Values Framework. Besides Competing Values Framework, we think that also for other types of theoretically motivated collaborator roles it could be possible to similarly identify strengths for each collaborator and the system could monitor that expected activity profiles most fertile for collaboration are met and if not the collaborators are asked to reach the expected activity profiles. Anyway, we decided to limit the scope of publication [P1] to cover estimating the activity frequencies only for the model Competing Values Framework.

It is challenging to empirically measure the pedagogical effect coming from automated guidance that aims to keep activity frequencies of collaborators close to the expected values. Anyway after publication of publication [P1] we carried out empirical user tests (n=20) that seemed to indicate that learners maintaining their activity frequencies most regularly close to expected values could generate more rich contribution to collaborative process of building knowledge structures than learners maintaining their activity frequencies less regularly close to expected values.

For all 20 members representing collaborator roles of Competing Values Framework, we measured how the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role depended on the sum of number of occurrences of all twelve types of activities of current member (measured proportionally). Based on Table 4.2, Appendix C shows the number of occurrences (measured proportionally) of twelve activities among four collaborator roles and also the sum of number of occurrences of all twelve types of activities of current member (measured proportionally). Based on Table 4.2 and Appendix C, Appendix D shows the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role. When each absolute value of difference for each member was coupled with the sum of number of occurrences of all twelve types of activities of current member (measured proportionally) we gained 240 pairs of values, and we sorted each pair of values into ascending order based on the absolute value of difference (as shown in Appendix D). The resulting sorted listing of paired values is illustrated in Figure 4.4.

Based on Figure 4.4 it seems that when the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role increases there is a decrease in the sum of number of occurrences of all activities (activities 1-12) of current

member (measured proportionally). We wanted to verify this notion with computations based on the sorted listing of Appendix D. For those 120 cases of 240 paired values having the lowest absolute values of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role it appears that the average of the sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally) is about 0.625401 (variance is about 0.046801), and for those 120 cases having the greatest absolute values of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role it appears that the average of the sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally) is about 0.574599 (variance is about 0.032165), i.e. the former average value is about 1.09 times the latter one. For all 240 paired values the pooled variance is about 0.039966.

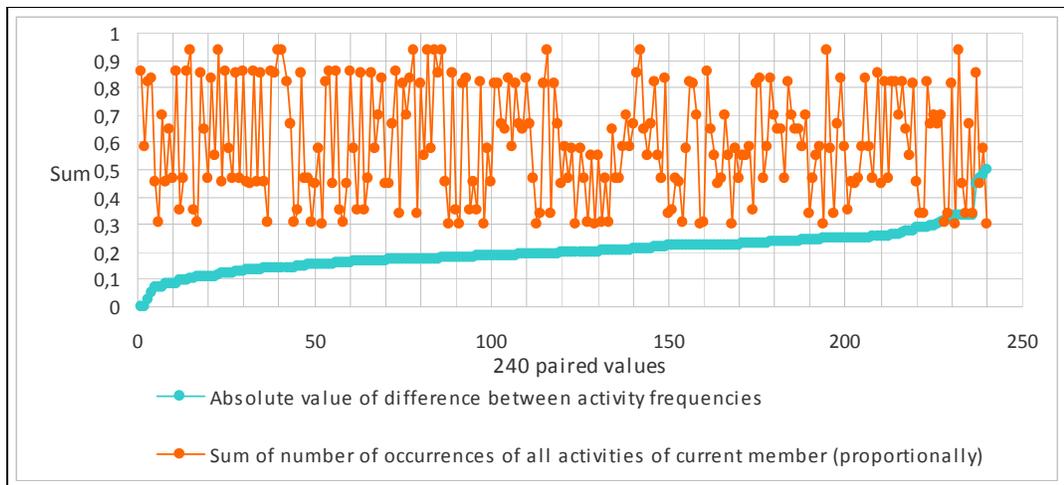


Figure 4.4. The dependence between the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role and the sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally). 240 paired values based on Appendix D have been sorted into ascending order based on the absolute value of difference.

Since effect of an educational intervention can be measured with effect size (Hattie 2009) we do it based on just mentioned values (computed as difference of average for first 120 cases and average for last 120 cases divided by square root of pooled variance). Effect size in favor of the average of the sums of number of occurrences of all activities (activities 1-12) of current member (measured proportionally) for 120 cases having the lowest absolute values of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role in contrast with the average of the sums of number of occurrences of all activities (activities 1-12) of current member (measured proportionally) for 120 cases

having the greatest absolute values of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role is about 0.25 (i.e. difference of 0.625401 and 0.574599 divided by square root of 0.039966). This effect size of 0.25 indicates such effects that based on previous research of Hattie (Hattie 2009) while belonging to effect size values in range of 0.15-0.40 correspond to effects of influences that can be expected to be gained from a teacher in a typical year of schooling and reaches the value of 0.25 that has been suggested as an benchmark for effect size that an intervention could be educationally significant ((Bloom et al. 2008) referring to (Tallmadge 1977)) (more details about the role of effect size is discussed in Chapter 10). Thus based on our experiments seem to indicate that learners maintaining their activity frequencies most regularly close to expected values could generate more rich contribution to collaborative process of building knowledge structures than learners maintaining their activity frequencies less regularly close to expected values.

We think that more detailed further analysis of correlation and causality about for example timing practices concerning the distribution of different activities of collaborators and following a specific order of performance can reveal new insight about how each individual collaborator role can proceed in collaboration activities most fruitfully and naturally thus offering best benefits both individually and collectively. Thus by getting more understanding about the characteristics and models governing each collaborator's typical fertile activities the system could then support best the learner by intervening fruitfully and supportingly at moments when it seems that the learners would benefit from doing something specific that however she now has not yet figured out to do.

Individual variation among persons having same collaborator role, causes that the suggested activity frequencies should not be seen as strict values but instead indicating approximate tendencies. Our empirical results with Competing Values Framework show that collaborator role of Coordinator-monitor has leading frequency in four types of activity, Facilitator-mentor has in four types of activity, Producer-director has in three types of activity and Innovator-broker in one type of activity. However, this does not necessitate that role Innovator-broker is more passive than other roles in collaboration in respect to all kinds of imaginable activities. If activity frequencies for additional alternative types of activities are measured in future research it may turn out that the number of leading frequencies for each role and balance of them is completely different. An important task for future research is to try to find most expressive way to classify and identify collaborator roles types, their strengths and measurable activities for each role.

We present now here additional findings and how they can be incorporated into our original model and how they affect our previous analysis and conclusion reported in the publication [P1]. It appeared that our heuristically approximated frequencies (see Appendix R) differed from the experimentally gained frequencies with some major features. Firstly, the heuristically approximated frequencies had a general difference that each unique type of performance had a distribution of frequencies that was unrealistically wide. This means that despite some extreme individual variations, the

general average difference between different collaborator roles remains in empirical values only in relatively small range. So instead of having several multiples of other frequencies (other frequencies being even 200–400 percent greater than others) typically we observed at most 200 percent greater frequencies.

Also our later experiments showed that we originally defined a too tight and strict threshold (20 percent) for the monitoring system to intervene with encouraging the user to modify the frequency of the activities belonging to their collaborator role. We now consider that the system should not be directly intervening depending on a fixed percentage in the activity level for a certain collaborator role but instead be relative to the broader distribution pattern of activity frequencies of the collaborator roles. We suggest giving tolerance for variation until the activity frequencies reach a new maximum or a minimum value. This means that for each type of activity the system does not intervene as long as the activity role having the highest value in expected activity frequency profile has not yet been passed above by the collaborator representing another role and as the activity role having the lowest value in expected activity frequency profile has not yet been passed below by the collaborator representing another role.

As briefly mentioned in publication [P6], our later supplementary empirical experiments with a group of 66 students also indicated that persons representing different collaborator roles based on Competing Values Framework produced distinctive exploration patterns in collective concept mapping as suggested in publication [P1]. These 66 students were a subsection of the group of 103 students having ages ranging from 15 to 18 years which was explained in Subchapter 3.9.

Table 4.4 shows the conceptual relationships having the highest number of occurrences for each of four collaborator roles of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (linking direction was not specified in relationships of concept maps). For each collaborator role we have indicated with an asterisk (*) those relationships that do not exist in listings of other collaborator roles in this table. Since among 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate) we show for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Even if from this small sample strong conclusions cannot be made, in Table 4.4 it seems to us that certain conceptual relationships occurred more frequently in concept mapping by certain collaborator roles of Competing Values Framework, and these promoted relationships can possibly even have same correlations with the characteristics associated with this collaborator role according to Competing Values Framework. Persons representing Innovator-broker role (create) associated with flexibility and readiness promoted for example relationship education↔school. Persons representing Coordinator-monitor role (control) associated with information management and communication promoted for example relationship school↔teacher. Persons representing Producer-director role (compete) associated with planning and goal-setting promoted

for example relationship education=work. Persons representing Facilitator-mentor role (collaborate) associated with cohesion and morale promoted for example relationship animal=god.

Table 4.4. In exploration patterns in collective concept mapping those conceptual relationships having the highest number of occurrences for each of four collaborator roles of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (linking direction was not specified in relationships of concept maps). For each collaborator role we have indicated with an asterisk (*) those relationships that do not exist in listings of other collaborator roles in this table. Since among 66 students 24 represented Producer-director role (compete), 14 Innovator-broker role (create), 14 Coordinator-monitor role (control) and 14 Facilitator-mentor role (collaborate) we show for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Facilitator-mentor role (collaborate) (n=14)		Producer-director role (compete) (n=24)			Coordinator-monitor role (control) (n=14)		Innovator-broker role (create) (n=14)	
relationship	occurrences	relationship	occurrences (n=24)	normalized occurrences ** (estimates corresponding to n=14)	relationship	occurrences	relationship	occurrences
family=home	3	family=love	5	2.92	friend=school	4	joy=sorrow	3
family=love	3	food=water *	4	2.33	father=mother *	3	birth=death	2
birth=death	2	education=work *	3	1.75	family=friend *	3	animal=dog *	2
friend=love	2	family=living *	3	1.75	home=house *	2	friend=school	2
animal=god *	2	friend=love	3	1.75	family=mother *	2	death=sorrow *	2
family=father	2	air=water *	2	1.17	family=father	2	death=living *	2
study=work *	2	fire=ground *	2	1.17	child=wife *	2	cat=dog	2
death=nature *	2	air=ground *	2	1.17	animal=family *	2	education=school *	2
birth=nature *	2	family=home	2	1.17	friend=hobby *	2	family=happiness *	2
living=purpose *	2	joy=sorrow	2	1.17	school=teacher *	2		
		breathing=human *	2	1.17	school=work *	2		
		friend=pet *	2	1.17	birth=death	2		
					diversity=nature *	2		
					family=reproduction *	2		
					birth=reproduction *	2		
					drink=food *	2		
					cat=dog	2		

Based on Table 4.4, Table 4.5 shows the most occurring concepts in conceptual relationships having the highest number of occurrences for each collaborator role of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role. For each collaborator role we have indicated with an asterisk (*) those concepts that do not exist in listings of other collaborator roles in this table. Like in Table 4.4 we show also in Table 4.5 for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Similarly as with Table 4.4, even if from this small sample strong conclusions cannot be made, in Table 4.5 it seems to us that certain concepts occurred more frequently in concept mapping by certain collaborator roles of Competing Values Framework, and these promoted concepts can possibly even have same correlations with the characteristics associated with this collaborator role according to Competing Values Framework. Persons representing Innovator-broker role (create) associated with flexibility and readiness promoted for example concept happiness. Persons representing Coordinator-monitor role (control) associated with information management and communication promoted for example concept diversity. Persons representing Producer-director role (compete) associated with planning and goal-setting promoted for example concept breathing. Persons representing Facilitator-mentor role (collaborate) associated with cohesion and morale promoted for example concept god.

Table 4.5. In exploration patterns in collective concept mapping those most occurring concepts in conceptual relationships having the highest number of occurrences for each collaborator role of Competing Values Framework when considering only those relationships mentioned by at least two representatives of this collaborator role (based on Table 4.4). For each collaborator role we have indicated with an asterisk (*) those concepts that do not exist in listings of other collaborator roles in this table. Like in Table 4.4 we show also in Table 4.5 for Producer-director role (compete) also values that have been normalized (indicated with a double asterisk (**)) to correspond the same number of students (14) that was the number of students of each of the other roles.

Facilitator-mentor role (collaborate) (n=14)		Producer-director role (compete) (n=24)			Coordinator-monitor role (control) (n=14)		Innovator-broker role (create) (n=14)	
concept	occurrences	concept	occurrences (n=24)	normalized occurrences ** (estimates corresponding to n=14)	concept	occurrences	concept	occurrences
family	8	family	10	5.83	family	11	death	6
love	5	love	8	4.67	friend	9	sorrow	5
birth	4	water *	6	3.5	school	8	dog	4
death	4	friend	5	2.92	father	5	school	4
nature	4	air *	4	2.33	mother *	5	joy	3
home	3	food	4	2.33	birth	4	animal	2
animal	2	ground *	4	2.33	reproduction *	4	birth	2
father	2	education	3	1.75	animal	2	cat	2
friend	2	living	3	1.75	cat	2	education	2
god *	2	work	3	1.75	child *	2	family	2
living	2	breathing *	2	1.17	death	2	friend	2
purpose *	2	fire *	2	1.17	diversity *	2	happyness *	2
study *	2	home	2	1.17	dog	2	living	2
work	2	human *	2	1.17	drink *	2		
		joy	2	1.17	food	2		
		pet *	2	1.17	hobby *	2		
		sorrow	2	1.17	home	2		
					house *	2		
					nature	2		
					teacher *	2		
					wife *	2		
					work	2		

Interestingly in both Table 4.4 and Table 4.5 it turned out that collaborator roles Producer-director role (compete) and Facilitator-mentor role (collaborate) seemed to have connectivity for concept love and collaborator roles Innovator-broker role (create) and Coordinator-monitor role (control) seemed to have connectivity for concept school. Thus when considering four quadrants of Competing Values Framework the two roles

belonging to opposite quadrants seem to possibly be coupled by prioritizing at least to some extent certain concepts and certain relationships.

4.4. Findings and their relation to the entity of the dissertation

In publication [P1] we proposed an educational framework that we referred to as a collaborative learning platform. The guidance automatically generated by the collaboration platform should enable enhancing each collaborator's creative output in accordance with the collaborator role they represent based on Competing Values Framework. In publication [P1] we suggested performing further extensive user tests that can evaluate our proposed collaborative learning platform and its methods in various educational contexts. We are interested in extracting statistical and causal correlations in the activity patterns of persons representing different collaborator roles.

Many traditional collaborative ideation techniques have been based on following some strict rules. However this may not take well into account the constantly evolving dynamics of a group and how the goals change through intermediary steps. The proposed collaborative learning platform tries to enable the creative resources of the group and its members to flexibly adapt and respond to the impulses gained in the flow of ideation. Therefore, the collaborative learning platform does not give strict constraints for the group activities although it makes the process rather fuzzy. Anyway, in all creative work one needs to accept some uncertainty and leave room for spontaneity. Besides individual analysis, we expect to be fruitful to examine interaction patterns between collaborators and how they accumulate their knowledge together. This could enable new ways to support characteristics of each pair-wise communication in a group. Identifying the general principles of interaction patterns could also provide insight about evolution of ideas in dialogue threads. One aspect of collaboration that requires specific emphasis in future systems is delivering a balanced ideation session that exploits available resources in a convergent fashion.

There are various theoretical approaches trying to explain and model diverse collaborator roles and thus our proposal presented in publication [P1] should be seen primarily as a base for developing supportive activities. We expect this initial collaborative learning platform to be applicable even irrespective from which actual model of collaborator roles are applied to give guidance for the collaborators to keep certain activity patterns following inside some suggested threshold limits. We provide a concrete illustration of this activity control and support with model based on Competing Values Framework and providing empirically gained activity frequency values concerning specific activities of collaborative knowledge construction process. Critical analysis about the publication [P1] shows that the original work has some shortcomings due to limited experimental testing. However, accompanied with results gained in augmenting empirical user tests we think that the work of publication [P1] offers a promising new type of computational collaborative learning platform for supporting educational collaborative activities and in addition offers experimentally defined parameter values to guide activities to follow fertile patterns. Despite the publication

[P1] refers to less known variation of Competing Values Framework (i.e. Innovation Genome Model) we think that our work described in publication [P1] can still well maintain its credibility since they are closely related models.

We think that publication [P1] fruitfully described a workflow for collaborative learning relying on mechanisms that are closely related to wiki based architecture and philosophy for using wikis. We think that the characteristics of collaborative learning platform described in publication [P1] forms a base of educational framework that can be flexibly extended in functionality with various computational methods suggested and described in detail in later publication that form this dissertation. Publication [P1] draws a basic outline about new model of learning environment, actors and their requirements and how on abstract level to address the needs of learners with software. In publication [P1] we have described some basic elements needed in the user interface and how they are used to convey and handle messages and representations about educational information.

In publication [P1] we introduce the idea of retrieving supplementing knowledge from the Wikipedia to support individual and collaborative knowledge adoption and acquisition; in later proposals we decided to focus analysis just on outlinks, not inlinks. In publications [P2], [P3] and [P4] we elaborate this idea of exploiting knowledge structure of the Wikipedia for letting the learner to explore pedagogically meaningfully along chained concepts. Also mechanism allowing reverting to earlier stages of knowledge construction process and keeping clear unique referencing system to earlier pieces of contribution (log of activities enabling individual tracking) have early indications and implication about the proposals that are presented in publications [P5] and [P6]. Publications [P5] and [P6] elaborate using wiki structure to combine individual contributions given as concept maps to a bigger collective entity and using the knowledge structure of the Wikipedia to find shortest path to traverse conceptual chains shared inside an entity formed by combining individual concept maps. The method could be enhanced with real-time updates (not requiring to press submit button), now possible to have conflicts if concurrent editing performed.

Chapter 5. Generating pedagogical concept maps from the Wikipedia

In publication [P2] we propose a new computational method for guided generation of pedagogical concept maps based on the hyperlink network of the *Wikipedia online encyclopedia* (<http://en.wikipedia.org>). On a more general level, we propose methodology for generating adaptive concept maps from open access online knowledge resources, such as wikis. *Wikis* are web sites freely built and edited by a community of volunteers. Following the principles of our method we have designed and implemented a prototype application extracting semantic relations from the articles of the Wikipedia free online encyclopedia. We think that corresponding to an *intelligent tutoring system* our proposed method enables creating customized learning objects in real-time based on collaborative recommendations.

We now here first explain basic idea and motivation about building pedagogical concept maps based on hyperlink network of the Wikipedia and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P2]. Figure 5.1 illustrates main idea of the method proposed in publication [P2].

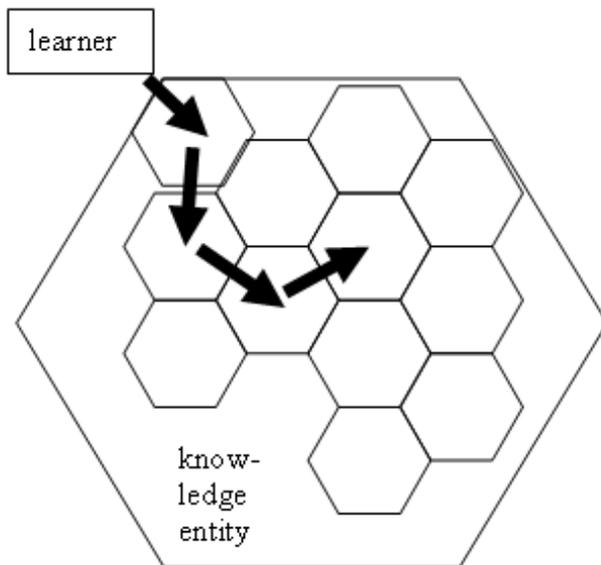


Figure 5.1. Main idea of the method proposed in publication [P2] for generating pedagogical concept maps based on exploring the hyperlink network of the Wikipedia.

In contrast with Figure 4.1 in which linked hexagons represented a collectively generated and gradually built concepts map, in Figure 5.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. In addition, instead of having collaborative learners, we are here now defining a strategy for a single learner traversing hyperlinks between articles. A shared edge between two hexagons indicate defined hyperlink between Wikipedia articles (arriving or departing hyperlink). The learner's exploration path in the hyperlink network so far is shown by a chain of arrows.

5.1. Exploiting the knowledge structure of the Wikipedia online encyclopedia

Previous research has identified various methods to access appropriate knowledge in the Wikipedia. Gregorowicz and Kramer (Gregorowicz & Kramer 2006) proposed to generate a robust term–concept network from the Wikipedia addressing actual concepts, alternate terms and related concepts, and Milne and Witten (Milne & Witten 2008b) proposed to disambiguate term–article mappings by exploiting three features: conditional probability, collocation and link distribution similarity. Gabrilovich and Markovitch (Gabrilovich & Markovitch 2009) suggested representing natural language semantics in a high-dimensional space of concepts based on calculating tf-idf weights (i.e. term frequency – inverse document frequency weights) for corresponding Wikipedia articles and reported that newer temporal versions of the Wikipedia gave a small but consistent improvement, and that use of inter-article links improved accuracy.

Knowledge mining from the Wikipedia has already been widely applied for various tasks (Medelyan et al. 2009), for example supporting the validation of relevant information, combining various knowledge resources and implementing an online association thesaurus ((Blohm et al. 2008); (Hoffmann et al. 2009); (Nakayama 2008)). Nakayama et al. (2008) showed that link structure mining improves both the accuracy and the scalability of semantic relations extraction from the Wikipedia. They propose three processes optimized for Wikipedia mining: fast pre-processing, part-of-speech tag tree analysis and mainstay (statement) extraction.

5.2. Educational exploration in the hyperlink network of the Wikipedia

The Wikipedia has been exploited educationally for returning specific answers to questions by an interface for command line queries (Kaisser 2008), biography quizzes (Higashinaka et al. 2007), and a tool assisting Wikipedia authors (Jijkoun & de Rijke 2006). However, indication of promising learning paths, unconstrained exploration and intuitive visualizations are typically missing in current solutions. (Kumar 2006) argues that in intelligent tutoring systems managing domain models and learner models can get support from so called “domain concept maps”. There does not currently exist many solutions supporting non-predefined verbal relations between concepts in the ontology and exploiting concept maps. (Zouaq et al. 2007b) proposed a layered model that with

natural language processing extracts concept maps from documents and organizes the generated knowledge into Web Ontology Language (OWL) document ontologies. By extracting concept-verb-concept triples and other relations with a parser their method generates a semantic network which can be further modified by a human expert with a visual map editor.

In publication [P2] we suggested extending the use of *ontologies* and *concept maps* into semantic modelling with the supply of the Wikipedia. We considered that the collaboratively maintained knowledge structure of the Wikipedia can serve as a both adaptive and expressive frame for implementing customized learning objects. We proposed extracting semantic relations from hyperlinks of an article and parsing compact explanations about them. The learner is encouraged to freely explore in real-time in the adaptively evolving personalized content based on hyperlink network of the Wikipedia. At the same time the path of exploration is represented in the form of gradually expanding concept maps. Positively, this proposed approach can be carried out with relatively simple computational methodology and ensures great personal freedom for the learner's exploration with an underlying optimistic hypothesis that she knows herself best her needs in selecting most suitable paths.

As already mentioned in Subchapter 3.5, it has been suggested that hypermedia learning programs can help learners representing cognitive style of *field independence* by offering multiple routes, free choice and visual control ((Chen 2002) referring to (Reiff 1996)), and can help learners representing cognitive style of *field dependence* by offering guided routes, labelling the role of current position along path and separate directions to required information ((Chen 2002) referring to ((Chou & Lin 1997); (Polson & Lewis 1990); (Hedberg & McNamara 1989))). Thus we think that the method for guided generation of pedagogical concept maps based on the hyperlink network of the Wikipedia that we proposed in publication [P2] should be considered to a large extent as a tailorable initial solution which can be further adapted to address the needs of both field dependent learners and field independent learners depending on the case. Field dependent learner can be supported in navigation by increasing in user interface increasingly for example direct guidance, links hiding, annotated links and link ordering whereas field independent learner can be supported in navigation by decreasing these features in user interface (Chen 2002).

Please note that besides concerning publication [P2], this supplementary notion about adaptively addressing both field dependent learners and field independent learners should be taken into account also in respect to proposals we made in all other publications belonging to this doctoral dissertation (i.e. in publications [P1]-[P9]). Some supplementing aspects concerning field dependency versus field independency are discussed in Subchapter 9.3 about implementing learning activities with learning concept networks (in which assisted construction mode can be considered to support field dependent learners and assisted evaluation mode to support field independent learners), in Subchapter 10.2 about experimental setup for recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network (which can be considered to support field independent learners) and in Subchapter 10.3 about experimental setup for recall of shown hyperlinks forming the shortest paths in

hyperlink network (which can be considered to support field dependent learners). Furthermore, in Subchapter 12.1 about cumulative exploration in conceptual network relying on spaced learning we discuss about generating a learning path based on traversing concepts in a pedagogic conceptual network and how to support both field independent learners (as discussed in original analysis of publication [P7]) and field dependent learners could be supported (as discussed in supplementing analysis made after publication [P7]).

We do not know previous work similar to our proposal in respect to learner-driven generation of labelled concept maps extracted from Wikipedia hyperlinks. For example, Wikipedia Roll merely focuses on browsing hyperlinks grouped in article's subchapters (Muthesius et al. 2008). Outside the Wikipedia domain, resembling concept mapping efforts include (Dey et al. 2007) and (Nasharuddin et al. 2008).

Natural and social networks, including the Wikipedia, form hierarchical cluster structures even without human coordination. These structures emerge following so called power law in for example article sizes, the number of connecting links, editing times and collaboration distribution (Buriol et al. 2006). These structures support the network in minimizing average paths between nodes and maximizing ability to recover if a random node fails. We suggest that management of ideas and concepts in human mind and collaborative learning may rely on an analogous cluster structure and thus favourable learning paths could rest on experimenting with the hyperlink structure of the Wikipedia. Our proposed method tries to facilitate exploiting these cluster structures for various educational purposes.

Since the knowledge in a wiki framework is already initially organized following human intuition, there is no need for extensive evaluation in large learning content space or heavy mining to reformulate information and to interpret it to a human user. A simple algorithm suffices to offer collectively generated recommendations for the learner how to gradually build learning paths along hyperlinks between Wikipedia articles. Even the choice between alternative learning paths can be given directly to the learner since the initial organization of knowledge and previous steps should be intuitive enough to support learner to make the best decisions for herself.

5.3. Building pedagogic concept maps from the Wikipedia

The proposed method is based on extracting semantic relations from Wikipedia articles on the request of a learner and gradually building a concept map online representing learning paths following the learner's initiative and interests. Evolving concept map provides functionalities of a customized learning object and an intelligent tutoring system that can be flexibly modified and reused. Table 5.1 illustrates the main activities involved in generation of pedagogic concept maps from the hyperlink network of the Wikipedia by using the proposed method.

Table 5.1. Main activities for the generation of pedagogic concept maps from the hyperlink network of the Wikipedia.

Step 1. Retrieval of a Wikipedia article as a html document from the web servers of the Wikipedia Foundation.
Step 2. Extraction of hyperlinks and sentences around them.
Step 3. Adding Penn Treebank part-of-speech conventions and tokenizing words with tags representing their role in sentence to the extracted sentences.
Step 4. Identifying verb closest to hyperlink and segment between surrounding nouns to form relation statement.
Step 5. Displaying list of hyperlinks target articles and their relation statements.
Step 6. Generating expanding concept map based on the hyperlinks that the learner decides to traverse.

The learner begins exploration by adding an initial concept about the learning topic manually as the first node of the concept map. Then the method retrieves a Wikipedia article having a title that matches the concept given by the learner. From the retrieved Wikipedia article the method extracts every hyperlink (consisting of the title and url (uniform resource locator) of target article and the anchor text) and the sentence surrounding it. For each extracted hyperlink the method generates a compressed explanation phrase based on the surrounding sentence. The compression is done by identifying a verb nearest to the hyperlink and taking into account only the text sequence between two adjacent nouns around this verb from the sentence and eliminating other less relevant words (for example redundant occurrences of titles of current article and hyperlink’s target article can possibly be eliminated from the sentence).

The hyperlinks are shown to the learner as a scrollable list in the original order of appearance thus promoting core definitions usually in the beginning of an article. Each row shows the title of hyperlink and its short explanation phrase. Following her intuition and evaluation, the learner can select one or more hyperlinks from the list. For the most recently selected hyperlink, the full original sentence is shown in a separate textbox letting the learner to verify that the compressed explanation phrase holds. By pressing the button “Selected to map” she can add selected hyperlinks as new child nodes of the currently active node, connected with directed arc. The node label is derived from the title of hyperlink and the arc label from the explanation phrase respectively. After adding new linked nodes, they can be used as initial concepts for further exploration. Step by step the learner establishes and proceeds in the most promising learning path for her needs.

We used *Apache Commons HttpClient module* to submit queries and to retrieve articles from the Wikipedia (Apache Commons 2009). We used *CRFTagger module* developed by Xuan-Hieu Phan as a *module of part-of-speech tagging* for English that according to the module’s documentation relies on first-order Markov conditional random fields model trained on Wall Street Journal portion of the Penn Treebank corpus

and is said to achieve accuracy of 97 percent (Phan 2006). Compared with rule based or lexicon dependent approach, a typical advantage of a Markov model is adaptivity to varying lexical contexts although at the cost of some accuracy. We designed and implemented the algorithms that extract hyperlinks with surrounding sentences and generate explanation phrases, and the algorithm coordinating existing modules. Figure 5.2 (originally published as Figure 1 in publication [P2]) illustrates the user interface of the prototype we have implemented based on the proposed method.

We wanted to verify that the proposed educational method in which the learner explores the hyperlink network of the Wikipedia can offer pedagogically meaningfully chainable segments of knowledge. Thus we have conducted experiments with our prototype by generating concept maps from the Wikipedia and evaluating their pedagogical quality with human reasoning. From a listing of 1000 most visited articles of the Wikipedia in 2008 (Wikistats Falsikon 2009) we randomly retrieved 20 articles and automatically generated an explanation phrase for each hyperlink they provided. We evaluated all these explanation phrases by labelling each of them as pedagogically useful, misleading or fuzzy (i.e. fuzzy meaning not clearly useful and not clearly misleading but somewhere in between) so that relying on our own personal teaching experiences we estimated how successfully ordinary school children could understand the meaning of these explanation phrases.

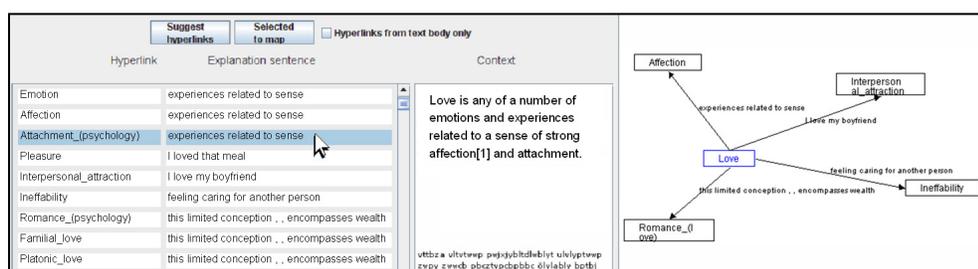


Figure 5.2. User interface of prototype while exploring the hyperlinks of Wikipedia article about Love (a detail).

As shown in Table 5.2 (originally published as Table 1 in publication [P2]), for all articles together, 81 percent of explanation phrases appeared to be useful, 11 percent misleading and 8 percent fuzzy. Only exception to the general success rate of at least 69 percent, is article about “Filippines” with 33 percent success only. A closer look revealed this being apparently due to having a lot of sentences referring to various cultural and geographical concepts that the method could not succeed in mapping correctly. We consider current success rate surprisingly good and convincing, especially in respect to high compression of explanation sentences.

To better understand educational potential of knowledge structures in the Wikipedia, we wanted to have a possibility to compare connectivity between 102 core concepts (shown in Table 3.4) in collection of concept maps drawn by students and in collection of corresponding 102 articles in the Wikipedia. An overview of these comparisons has been published in publication [P9] and we present here now extended more detailed results. To make this comparison process more stable and transparent we

decided to mainly rely on one fixed temporal version of the Wikipedia articles and hyperlink network that have been available online in the Wikipedia in the beginning of March 2008 and we used most preferably the last edited versions of articles and hyperlinks by date 3 March 2008. This specific date was partially motivated by experiments that we made with an online database service “Six degrees of Wikipedia” enabling to make queries about connectivity of Wikipedia articles based on version 3 March 2008 (Dolan 2011) (as discussed in publication [P6] and Chapter 9).

Table 5.2 (originally published as Table 1 in publication [P2]). Distribution of useful, misleading and fuzzy explanation phrases generated for hyperlinks of twenty Wikipedia articles separately. The success percentage indicates the proportion of useful phrases to all phrases.

	Lion	Italy	Radiohead	Jesse McCartney	Hancock (film)	Pink Floyd	Bow Wow	Philippines	Judaism	John Cena	Kenya	Linux	Star Wars: The Clone Wars (film)	Iraq War	Terminator Salvation	ABBA	Florida	Two-Face	Religion	Peru	Σ
Explanations	38	48	29	5	18	32	12	18	46	29	15	23	21	39	18	27	15	36	42	32	543
- useful	33	41	24	4	15	22	11	6	39	25	14	16	15	28	15	26	12	29	38	26	439
- misleading	4	5	3	0	2	5	0	7	5	4	1	4	3	4	1	1	2	3	3	5	62
- fuzzy	1	2	2	1	1	5	1	5	2	0	0	3	3	7	2	0	1	4	1	1	42
Success	87%	85%	83%	80%	83%	69%	92%	33%	85%	86%	93%	70%	71%	72%	83%	96%	80%	81%	90%	81%	81%

Appendix G shows how much in *hyperlink network of the Wikipedia* each of the 102 core concepts is linked (with a specified direction) to any possible concept or to 102 core concepts. Appendix G also shows how much linking departs from the *full text section* of each Wikipedia article ((i.e. when considering those hyperlinks that are mentioned in the full text in Wikipedia article) or from only *intro text section* of each Wikipedia article (i.e. when considering only those hyperlinks that are mentioned only in the very beginning of text in Wikipedia article, typically before table of index, thus often trying to offer a relatively compact definition about the article). In addition, for each of 102 core concept it is shown how much it occurs as start concept, end concept or start/end concept in hyperlinks.

Appendix H extends information of Appendix G by showing how much in *concept maps generated by students* each of 102 core concepts is connected (without a specified direction, thus either as start/end concept) to 102 core concepts when considering each connection with or without duplicates, considering only relationships mentioned by at least two students (based on 145 core relationships shown in Table 3.9).

It turned out that in the Wikipedia altogether 20512 hyperlinks (14907 unique hyperlinks) depart from full text section of 102 core concepts to any possible concept, average value being 201.1 hyperlinks and median value 151.5 hyperlinks. When limiting observation to only intro text section, altogether 1243 hyperlinks (1055 unique hyperlinks) depart from intro text section of 102 core concepts to any possible concept, average value being 14.0 hyperlinks and median value 11 hyperlinks. We identified that between 102 core concepts there are altogether 422 unique hyperlinks in hyperlink network of the Wikipedia.

When considering only linking between 102 core concepts and hyperlinks departing from a full text section, 85 of the 102 core concepts occur as an end concept in

hyperlinks and 88 of the 102 core concepts as a start concept in hyperlinks, and 93 of the 102 core concepts as a start or an end concept in hyperlinks. For hyperlinks departing from a full text section, on average a concept belonging to the 102 core concepts occurs as an end concept in a hyperlink for 4.1 other core concepts, as a start concept in a hyperlink for 4.1 other core concepts, and as a start or an end concept in a hyperlink for 6.4 other core concepts (median values being 3.5, 3 and 5 respectively).

When considering only linking between 102 core concepts and hyperlinks departing from only into text section, 43 of 102 core concepts occur as end concept in hyperlinks and 60 of 102 core concepts as start concept in hyperlinks, and 70 of 102 core concepts as start or end concept in hyperlinks. For hyperlinks departing from only into text section, on average a concept belonging to 102 core concepts occurs as an end concept in hyperlink for 1.1 other core concepts, as a start concept in hyperlink for 1.0 other core concepts, and as a start or an end concept in hyperlink for 1.8 other core concepts (median values being 1, 0 and 1 respectively).

Thus it seems that when having limited computational resources a simple and relatively successful solution to filter useful hyperlinks to support exploration of hyperlinks can be to rely on just those hyperlinks that depart from only into text section of a Wikipedia article since even in our small sample of 102 core concepts there seems to remain some kind of connectivity so that there is on average one hyperlink linking from a core concept to some other core concept.

These results about hyperlinks in the Wikipedia can be contrasted with results about relationships in concept maps drawn by students, considering only relationships mentioned by at least two students. In concept maps when considering only relationships between 102 core concepts, 75 of 102 core concepts occur as start or end concept in relationships (75 of 102 core concepts if word brother can be seen representing word sister since in the Wikipedia both words represent word sibling). On average a concept belonging to 102 core concepts occurs as a start or an end concept in relationship for 2.8 other core concepts (median value being 1).

Based on Appendix H for each of five comparison tests Table 5.3 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and the number of unique start/end concepts in relationships of concept maps for each of 102 core concepts. It turns out that only one of five null hypothesis, the null hypothesis H_k s of Bootstrap version of Kolmogorov-Smirnov two-sample test, becomes rejected based on significance level of $p < 0.05$.

To facilitate identifying possible similarities between frequency distributions of Appendix H we transformed for representation of Table 5.3 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts has a weighting parameter 1 and scaled

frequency distribution of number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts has a weighting parameter 3.3. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.3. Degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and the number of unique start/end concepts in relationships of concept maps for each of 102 core concepts.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (scaled)	number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.02651 (null hypothesis Hks rejected)	gamma=0.1418564 (standard error 0.1581316); null hypothesis Hgk not rejected (p=0.3696773)	rho=0.1642973; null hypothesis Hsr not rejected (p=0.09892)	tau=0.1251973; null hypothesis Hkr not rejected (p=0.09208)

Based on Appendix H Figure 5.3 in subfigure a visualizes scaled frequency distributions about number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts, and in subfigure b visualizes correlation between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in in relationships of concept maps for each of 102 core concepts.

Table 5.4 illustrates how comparison of connectivity between 102 core concepts in collection of concept maps drawn by students and in article collection of the Wikipedia needs to address the fact that some parts of these collections are not overlapping and thus are not directly comparable (explained originally in publication [P9]). In addition, in this comparison it needs to be noted that inherently the relationships in concept maps drawn by students do not have specified pointing direction whereas hyperlinks in the Wikipedia have a specified pointing direction. Also please note that in further analysis about concept maps we consider only relationships mentioned by at least two students (based on 145 core relationships shown in Table 3.9).

Based on five comparison tests shown in Table 5.3 and visualization of Figure 5.3 it can be seen that the number of unique start/end concepts in hyperlinks of the Wikipedia and in relationships of concept maps for each of 102 core concepts is not following a symmetric parallel decreasing trend. Instead it seems that concepts having high level of occurrences in the Wikipedia are largely different than those concepts getting high level of occurrences in concept maps.

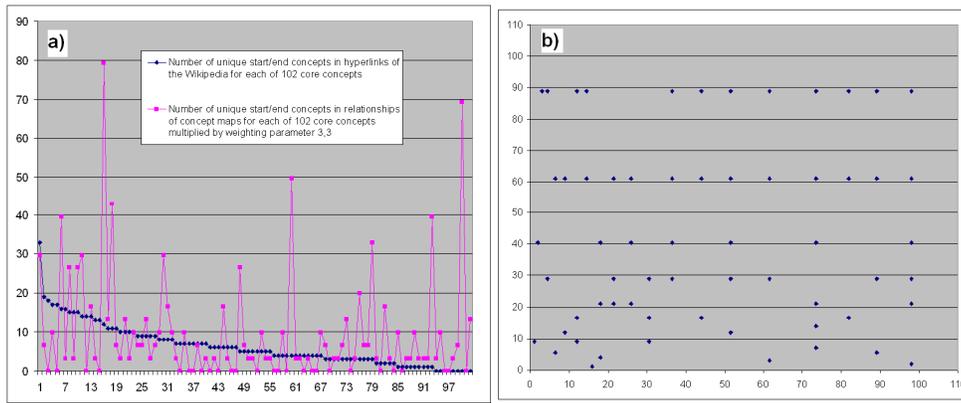


Figure 5.3. a) Scaled frequency distributions about number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts and number of unique start/end concepts in relationships of concept maps for each of 102 core concepts. Frequencies are shown so that along x axis the 102 core concepts are listed in decreasing order in respect to number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (i.e. core concepts are listed always in same ordering). b) Visualization of correlations between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 102 core concepts (x) and number of unique start/end concepts in relationships of concept maps for each of 102 core concepts (y).

Table 5.4. Connectivity between 102 core concepts in collection of concept maps drawn by students (n=103) and in article collection of the Wikipedia (considering in concept maps only relationships mentioned by at least two students).

Description of measured value	In collection of concept maps drawn by students	In article collection of the Wikipedia
Number of unique relationships/hyperlinks between 102 core concepts	145 (relationships)	422 (hyperlinks)
- number of distinct concepts in relationships of concept maps and in hyperlinks of the Wikipedia	75	93
- number of shared concepts, i.e. number of overlapping distinct concepts in relationships of concept maps and in hyperlinks of the Wikipedia	69	69
Number of relationships/hyperlinks between shared concepts	113 (relationships), containing 64 unique concepts	248 (hyperlinks), containing 67 unique concepts
- number of shared relationships, i.e. number of overlapping relationships/hyperlinks concerning shared concepts	44 relationships	65 hyperlinks (42 of these hyperlinks have another hyperlink going into opposite direction)
- number of distinct concepts in shared relationships	43	43

As discussed already earlier in text before Table 3.9, there are *145 core relationships* connecting *102 core concepts* in concept maps drawn by students and these relationships – each mentioned by at least two students – use only 75 concepts of 102 core concepts (75 of 102 core concepts if word “brother” can be seen representing word “sister” since in the Wikipedia concept Sibling represents both concept Brother and concept Sister)¹³. Since concepts “cloth” (corresponds to Clothing) and “shoe” remain

¹³ Thus in connectivity concerning concept maps there is absence of 27 of 102 core concepts: “baby” (corresponds to Infant), “bed”, “bread”, “childhood”, “city”, “eating”, “evolution”, “exam” (corresponds to Test_(assessment)), “flower”, “forest”, “fun”, “future”, “goal_(to_achieve)”, “goodness”, “hate”

outside otherwise interconnected entity, these two concepts are excluded and we use in further analysis only 73 concepts concerning connectivity in the concept maps.

Relying on last edited versions of articles and hyperlinks by date 3 March 2008 in the Wikipedia, we found altogether 422 *hyperlinks* in the Wikipedia between 102 core concepts, shown in Appendix I. 192 of these 422 hyperlinks had an hyperlink going to opposite direction, and 230 of these 422 hyperlinks did not have a hyperlink going to opposite direction. In these 422 hyperlinks in the Wikipedia connecting 102 core concepts we identified 93 distinct concepts of 102 core concepts¹⁴. Since concepts Dream and Bed remain outside otherwise interconnected entity, these two concepts are excluded and we use in further analysis only 91 concepts concerning connectivity in the Wikipedia.

Among 102 core concepts, when considering number of overlapping distinct concepts in relationships of concept maps (considering only relationships mentioned by at least two students, based on 145 core relationships shown in Table 3.9) and hyperlinks of the Wikipedia, we identified 69 *shared concepts*. Based on Appendix H showing how each of 102 core concepts is connected to other concepts belonging to 102 core concepts—both in the Wikipedia and in concept maps—we generated Table 5.5 to show a comparison of these two connectivities among just a subset of 69 shared concepts. Thus Table 5.5 shows for both the Wikipedia and concept maps 69 shared concepts in descending ranking in respect to appearing as either start or end concept among 102 core concepts either in hyperlinks of the Wikipedia or in relationships of concept maps respectively.

Based on Table 5.5 for each of five comparison tests Table 5.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts and the number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts (explained originally in publication [P9]).

(corresponds to Hatred), “marriage”, “paper”, “pen”, “people”, “philosophy”, “pleasure”, “rain”, “sadness”, “sport”, “succeeding” (corresponds to Management), “time” and “world”.

¹⁴ Thus in connectivity concerning the Wikipedia there is absence of 9 of 102 core concepts: Chair, Environment, Fun, Goodness, Growing, Holiday, Living, Management and Study.

Table 5.5 part 1 of 2 (starts here and continues on next page). Comparison between conceptual networks of concept maps generated by students (n=103) and hyperlink network of corresponding Wikipedia articles when analysing 69 shared concepts.

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Concept</i>	<i>Occurrences as start or end concept in relationships between concepts</i>	<i>Ranking</i>	<i>Concept</i>	<i>Occurrences as start or end concept in hyperlinks between concepts</i>	<i>Ranking (how many positions higher than ranking of concept maps drawn by students)</i>
family	24	1	Human	33	1 (+7s)
friend	15	2	Plant	19	2 (+35s)
nature	13	3	Education	17	3 (+23.5s)
love	12	4.5s	Love	16	4.5s (0s)
work	12	4.5s	Oxygen	16	4.5s (+51.5s)
school	10	6	Animal	15	7s (+4s)
death	9	8s	Religion	15	7s (+49s)
health	9	8s	Water	15	7s (+4s)
human	9	8s	Death	14	9.5s (-1.5s)
animal	8	11s	Food	14	9.5s (+6s)
birth	8	11s	Biology	13	11 (+45s)
water	8	11s	Family	12	12 (-11)
home	6	13	Leisure (corresponds to "freetime")	11	14s (+5.5s)
food	5	15.5s	Nature	11	14s (-11s)
hobby	5	15.5s	Organism	11	14s (+23s)
house	5	15.5s	Adolescence (corresponds to "young (person)")	10	17.5s (+38.5s)
joy	5	15.5s	Child	10	17.5s (+2s)
child	4	19.5s	Emotion	10	17.5s (+38.5s)
dog	4	19.5s	Television	10	17.5s (+9s)
freetime	4	19.5s	Atmosphere_of_Earth (corresponds to "air")	9	22s (+15s)
mother	4	19.5s	God	9	22s (+15s)
computer	3	26.5s	Mother	9	22s (-2.5s)
education	3	26.5s	Music	9	22s (+34s)
father	3	26.5s	Sibling (corresponds to "sister")	9	22s (+15s)
ground	3	26.5s	Happiness	8	26.5s (0s)
happiness	3	26.5s	Health	8	26.5s (-18.5s)
pet	3	26.5s	Hobby	8	26.5s (-11s)
sorrow	3	26.5s	Sun	8	26.5s (0s)
sun	3	26.5s	Diet_(nutrition) (corresponds to "nutriment")	7	30.5s (+25.5s)
television	3	26.5s	Father	7	30.5s (-4s)
tree	3	26.5s	Old_age (corresponds to "elderness")	7	30.5s (+6.5s)
air	2	37s	War	7	30.5s (+25.5s)
car	2	37s	Clothing (corresponds to "cloth")	6	34s (+22s)
clock	2	37s	House	6	34s (-18.5s)
disease	2	37s	Parent	6	34s (+22s)

Table 5.5 part 2 of 2 (started on previous page and continues here).

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Concept</i>	<i>Occurrences as start or end concept in relationships between concepts</i>	<i>Ranking</i>	<i>Concept</i>	<i>Occurrences as start or end concept in hyperlinks between concepts</i>	<i>Ranking (how many positions higher than ranking of concept maps drawn by students)</i>
elderness	2	37s	Birth	5	39s (-28s)
god	2	37s	Disease	5	39s (-2s)
money	2	37s	Experience	5	39s (+17s)
organism	2	37s	Learning	5	39s (+17s)
party	2	37s	Pet	5	39s (-12.5s)
plant	2	37s	Purpose	5	39s (+17s)
sister	2 ("brother")	37s	Teacher	5	39s (+17s)
biology	1	56s	Computer	4	45.5s (-19s)
book	1	56s	Friendship (corresponds to "friend")	4	45.5s (-43.5s)
cat	1	56s	Hospital	4	45.5s (+10.5s)
cloth	1	56s	Light	4	45.5s (+10.5s)
dream_(sleeping)	1	56s	Physical_fitness (corresponds to "physical_training")	4	45.5s (+10.5s)
emotion	1	56s	Tree	4	45.5s (-19s)
experience	1	56s	Automobile (corresponds to "car")	3	53.5s (-16.5s)
heart	1	56s	Book	3	53.5s (+2.5s)
hospital	1	56s	Cat	3	53.5s (+2.5s)
learning	1	56s	Clock	3	53.5s (-16.5s)
light	1	56s	Dog	3	53.5s (-34s)
music	1	56s	Heart	3	53.5s (+2.5s)
nutriment	1	56s	Home	3	53.5s (-40.5s)
oxygen	1	56s	Money	3	53.5s (-16.5s)
parent	1	56s	Party	3	53.5s (-16.5s)
peace	1	56s	School	3	53.5s (-47.5s)
phone	1	56s	Dream	2	60s (-4s)
physical_training	1	56s	Joy	2	60s (-44.5s)
purpose	1	56s	Peace	2	60s (-4s)
religion	1	56s	Ground	1	65.5s (-39s)
sea	1	56s	Sea	1	65.5s (-9.5s)
shoe	1	56s	Shoe	1	65.5s (-9.5s)
summer	1	56s	Sorrow	1	65.5s (-39s)
teacher	1	56s	Summer	1	65.5s (-9.5s)
travel	1	56s	Telephone (corresponds to "phone")	1	65.5s (-9.5s)
war	1	56s	Travel	1	65.5s (-9.5s)
young_(person)	1	56s	Work	1	65.5s (-61s)

To facilitate identifying possible similarities between frequency distributions of Table 5.5 we transformed for representation of Table 5.6 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts has a weighting parameter 1 and scaled frequency distribution of number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts has a weighting parameter 0.4. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.6. Degrees of dependency between the number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts and the number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts (n=103).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of unique start/end concepts in relationships of concept maps for each of 69 shared concepts (scaled)	number of unique start/end concepts in hyperlinks of the Wikipedia for each of 69 shared concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.04895 (null hypothesis Hks rejected)	gamma=0.2460317 (standard error 0.1916975); null hypothesis Hgk not rejected (p=0.1993388)	rho=0.2746393; null hypothesis Hsr rejected (p=0.02239)	tau=0.213873; null hypothesis Hkr rejected (p=0.01925)

Based on Table 5.5 Figure 5.4 visualizes correlation between ranking values of number of unique start/end concepts in hyperlinks of the Wikipedia among 102 core concepts for each of 69 shared concepts and number of unique start/end concepts in relationships of concept maps among 102 core concepts for each of 69 shared concepts.

Furthermore based on Table 5.5 we generated Table 5.7 to show concepts having the greatest and smallest ranking difference when comparing occurrences as start or end concept among 102 core concepts for each of 69 shared concepts either in hyperlinks of the Wikipedia or in relationships of concept maps in respect to concepts more occurring in hyperlinks of the Wikipedia, concepts more occurring in concept maps, and concepts with the smallest difference when considering occurrences in concept maps minus occurrences in hyperlinks of the Wikipedia.

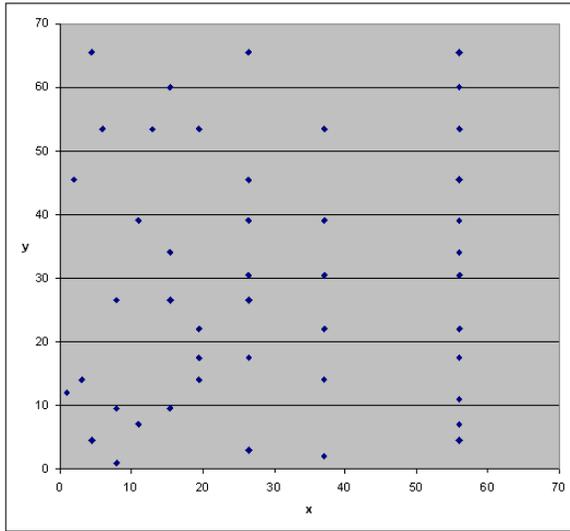


Figure 5.4. Visualization of correlation between ranking of concepts appearing as either start or end concept in relationships of concept maps drawn by students (x) (n=103) and ranking of concepts appearing as either start or end concept in hyperlinks of the Wikipedia (y), in respect to 69 shared concepts among 102 core concepts.

Based on Table 5.7 it seems that concepts occurring more as start/end concepts in the Wikipedia include more formal themes representing relatively high levels of classification (for example Oxygen, Religion, Biology, Adolescence and Emotion) whereas concepts occurring more as start/end concepts in the concept maps include less formal themes near a personal viewpoint (for example Work, School, Joy, Friendship and Home), and relatively neutral balancing between the Wikipedia and concept maps emerges with such central concepts as child, mother and father. Even if both Wikipedia and concept maps cover similar kind of topics they emphasize different themes so that for example concerning theme of emotions the Wikipedia emphasizes Emotion and Music, concept maps emphasize Joy and Sorrow, and neutral balancing emerges with Happiness and Love.

Table 5.8 shows how each of 69 shared concepts have been connected to other concepts inside collection of 69 shared concepts, both in Wikipedia and concept maps (considering in concept maps only relationships mentioned by at least two students). So while Table 5.5 and Table 5.7 show connectivity for 69 shared concepts among 102 core concepts now Table 5.8 shows connectivity for 69 shared concepts only among 69 shared concepts.

Table 5.7. Some of the greatest and smallest ranking differences for concepts in respect to occurrences as start/end concepts among 102 core concepts for each of 69 shared concepts in relationships of concept maps drawn by students versus occurrences as start/end concepts among 102 core concepts for each of 69 shared concepts in hyperlinks of the Wikipedia.

Some of the greatest ranking differences for concepts having higher ranking position for occurrences as start/end nodes in hyperlinks of the Wikipedia than in relationships of concept maps drawn by students		Some of the greatest ranking differences for concepts having lower ranking position for occurrences as start/end nodes in hyperlinks of the Wikipedia than in relationships of concept maps drawn by students		Some of the smallest ranking differences for concepts between ranking based on occurrences as start/end nodes in hyperlinks of the Wikipedia and in relationships of concept maps drawn by students	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Oxygen	+51.5s	Work	-61s	Happiness; Love; Sun	0s
Religion	+49s	School	-47.5s	Death	-1.5s
Biology	+45s	Joy	-44.5s	Child	+2s
Adolescence; Emotion	+38.5s	Friendship	-43.5s	Disease	-2s
Plant	+35s	Home	-40.5s	Book; Cat; Heart	+2.5s
Music	+34s	Ground; Sorrow	-39s	Mother	-2.5s
Diet_(nutrition); War	+25.5s	Dog	-34s	Animal; Water	+4s
Education	+23.5s	Birth	-28s	Dream; Father; Peace	-4s
Organism	+23s	Computer; Tree	-19s	Leisure	+5.5s

When considering connectivity between 69 shared concepts (i.e. from a concept belonging to 69 shared concepts to another concept belonging to 69 shared concepts), there are 248 hyperlinks in the Wikipedia, containing 67 unique concepts, and respectively there are 113 relationships in concept maps, containing 64 unique concepts (considering only relationships mentioned by at least two students). In 248 hyperlinks connecting 69 shared concepts in the Wikipedia, there are 114 hyperlinks that have a hyperlink going also into opposite direction inside 69 shared concepts.

When considering overlap in connectivity between 69 shared concepts both in the Wikipedia and in concept maps (considering only relationships mentioned by at least two students) this overlap contains altogether 44 relationships of concept maps and 65 hyperlinks of the Wikipedia (42 of these hyperlinks have another hyperlink going into opposite direction). These 44 relationships and 65 hyperlinks contain 43 unique concepts. This seems to indicate that even if we started analysis with a collection of 102 inter-linked concepts generated by students it turns out that comparison to hyperlinks between corresponding Wikipedia articles brings available set of concepts having shared linkage to a reduced number of 43 concepts meaning about 42 percent of originally observed 102 concepts.

Table 5.8 part 1 of 2 (starts here and continues on next page). Connectivity between 69 shared concepts in concept maps drawn by students (n=103) and in hyperlink network of the Wikipedia.

69 shared concepts	Conceptual network of concept maps drawn by students	Hyperlink network of the Wikipedia			
		Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Possibility to reach observed concept by surfing in hyperlink network connecting 69 shared concepts in the Wikipedia when starting from concepts Human ¹⁵
Adolescence (<i>young (person)</i>)	1	7	6	4	along link
Animal	7	12	9	8	along link
Atmosphere_of_Earth (<i>air</i>)	2	7	4	7	along link
Automobile (<i>car</i>)	2	2	2	1	along link
Biology	1	11	10	7	along link
Birth	6	5	1	4	along link
Book	1	2	1	1	against link
Cat	1	3	2	3	along link
Child	4	7	5	6	along link
Clock	2	1	0	1	against link
Clothing (<i>cloth</i>)	1	4	2	2	along link
Computer	3	4	2	2	along link
Death	8	11	5	8	along link
Diet_(nutrition) (<i>nutriment</i>)	1	7	5	4	along link
Disease	2	5	5	1	along link
Dog	4	3	2	3	along link
Dream	1	1	0	1	against link
Education	2	12	7	10	along link
Emotion	1	5	3	4	along link
Experience	1	2	2	0	along link
Family	21	11	11	5	along link
Father	3	6	5	5	along link
Food	4	12	3	10	along link
Friendship (<i>friend</i>)	13	3	1	3	along link
God	2	6	4	3	along link
Ground	3	0	0	0	not reachable
Happiness	3	5	5	2	along link
Health	9	7	6	5	along link
Heart	1	3	3	0	along link
Hobby	5	6	0	6	against link
Home	6	3	1	3	along link
Hospital	1	2	0	2	against link

¹⁵ Explanation for notations: along link = traversing along existing directions of hyperlinks is sufficient to reach observed concept when starting from concept Human; against link = traversing against existing directions of hyperlinks is needed; not reachable = observed concept is not reachable at all even if trying to proceed along and against existing directions of hyperlinks.

Table 5.8 part 2 of 2 (started on previous page and continues here).

69 shared concepts	Conceptual network of concept maps drawn by students	Hyperlink network of the Wikipedia			
		Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 69 shared concepts	Possibility to reach observed concept by surfing in hyperlink network connecting 69 shared concepts in the Wikipedia when starting from concepts Human ¹⁶
House	4	6	3	4	along link
Human	8	25	11	16	along link
Joy	4	2	2	1	along link
Learning	1	4	2	3	along link
Leisure (<i>freetime</i>)	4	8	5	5	along link
Light	1	3	1	2	along link
Love	11	11	7	6	along link
Money	2	2	0	2	against link
Mother	4	8	5	7	along link
Music	0	5	3	2	along link
Nature	11	9	5	8	along link
Old_age (<i>elderness</i>)	2	5	3	4	along link
Organism	1	9	8	3	along link
Oxygen	1	12	10	6	along link
Parent	1	6	4	6	along link
Party	1	3	0	3	against link
Peace	0	2	1	2	along link
Pet	3	4	3	3	along link
Physical_fitness (<i>physical_training</i>)	1	4	3	2	along link
Plant	2	13	11	9	along link
Purpose	0	2	0	2	against link
Religion	0	8	7	3	along link
School	8	3	3	2	along link
Sea	1	1	1	1	along link
Shoe	1	1	0	1	against link
Sibling (<i>sister/brother</i>)	2	8	7	5	along link
Sorrow	2	0	0	0	not reachable
Summer	1	1	0	1	against link
Sun	2	7	6	2	along link
Teacher	1	3	2	3	along link
Telephone (<i>phone</i>)	1	1	1	0	along link
Television	3	8	8	0	along link
Travel	0	1	1	0	along link
Tree	3	3	1	2	along link
War	1	6	4	3	along link
Water	7	12	7	8	along link
Work	9	1	1	0	along link

¹⁶ Explanation for notations: along link = traversing along existing directions of hyperlinks is sufficient to reach observed concept when starting from concept Human; against link = traversing against existing directions of hyperlinks is needed; not reachable = observed concept is not reachable at all even if trying to proceed along and against existing directions of hyperlinks.

Please note that to keep notation relatively compact in further analysis we often compare concepts of the Wikipedia and concepts gained from students through word lists or concept maps so that we write concepts using only that form which is used in the Wikipedia. Thus even if actually making comparison between occurrences of concept “friend” in word lists or concept maps of students and occurrences of concept Friendship in the Wikipedia we often refer to them both with just notation Friendship (as shown for example in Table 5.9 and Figure 5.5).

Table 5.9. Overlap in connectivity between 69 shared concepts in concept maps drawn by students (n=103) and Wikipedia thus showing 44 shared links (shared by both the Wikipedia and concept maps, considering only relationships mentioned by at least two students). In concept maps there is a relationship between each pair of concepts (direction of conceptual relationships in concept maps are not specified) and in hyperlinks of the Wikipedia there is unidirectional linking (marked with ->) or bidirectional linking (marked with <->) between each pair of concept.

<i>Pair of concepts and their linking in the Wikipedia</i>	<i>Pair of concepts and their linking in the Wikipedia (continued)</i>
Animal <-> Human	Friendship <-> Love
Animal <-> Nature	Health -> Disease
Biology <-> Nature	Health <-> Physical_fitness
Birth -> Death	Hobby -> Leisure
Cat <-> Dog	Home -> Family
Child <-> Family	Home <-> House
Clock -> Computer	House -> Family
Computer -> Television	Human -> Family
Death <-> Disease	Human -> Love
Death -> Human	Leisure -> Television
Death -> War	Love -> Family
Dog <-> Pet	Love -> Happiness
Education <-> School	Mother -> Love
Emotion <-> Love	Nature -> Human
Family <-> Father	Nature <-> Plant
Family <-> Mother	Nature -> Sun
Family <-> Sibling	Old_age -> Death
Father <-> Mother	Oxygen <-> Water
Food -> Animal	Plant -> Tree
Food <-> Health	School <-> Teacher
Food -> Water	Sea <-> Water
Friendship -> Adolescence	Shoe -> Clothing
<i>(listing continues on column 2)</i>	

Table 5.9 and Figure 5.5 show the overlap in connectivity between 69 shared concepts (explained originally in publication [P9]). When comparing Figure 3.3 containing 74 interconnected concepts (73 concepts plus an additional concept brother) with Figure 5.5 it appears that both these figures share several actively connected concepts (for example Family and Human) but some of the actively connected concepts of former figure are missing in latter figure (for example Work). In this publication we use notation conceptA → conceptB (i.e. two concepts separated with an arrow containing consecutive symbols of hyphen and greater-than sign or less-than sign) to represent directional links, hyperlinks or traversals from one concept to another concept.

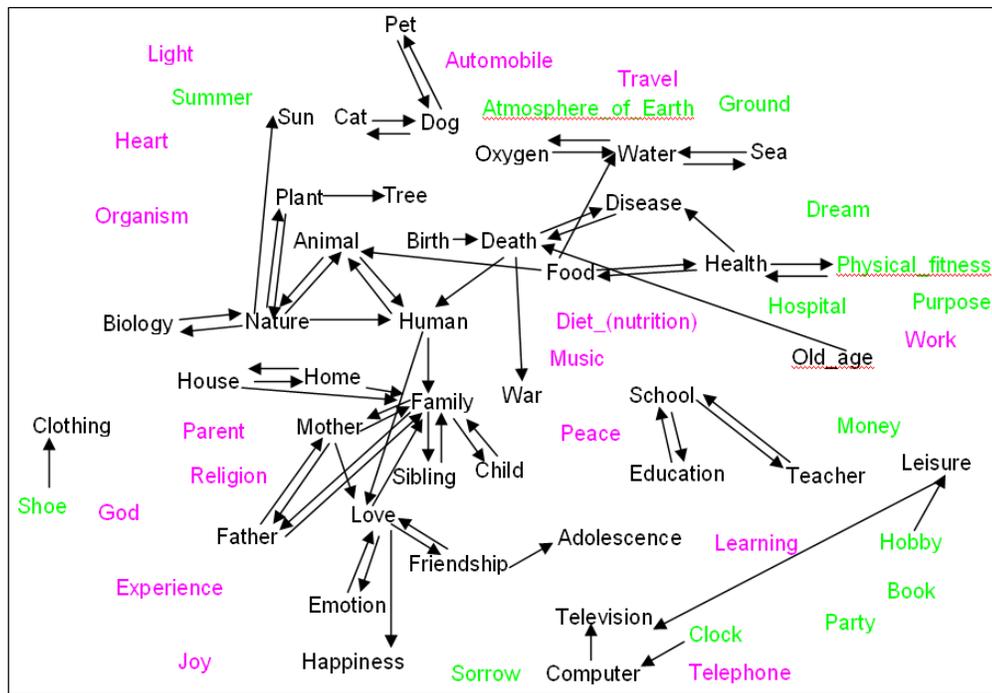


Figure 5.5 (originally published as Figure 1a in publication [P9]). Black arrows show overlapping connectivity between 69 shared concepts in concept maps drawn by students ($n=103$) and the Wikipedia thus showing 44 shared links (shared by both the Wikipedia and concept maps, considering only relationships mentioned by at least two students) connecting 43 concepts. Formation of “hyperlink network of 55 concepts” for exploration experiments originated with all 69 concepts but those concepts that we decided to exclude are shown with green font and thus concepts with black and pink font are all concepts included in “hyperlink network of 55 concepts”. Black arrows indicate linking direction only in the Wikipedia since directions of conceptual relationships in concept maps are not specified.

In 113 relationships in concept maps connecting 69 shared concepts (considering only relationships mentioned by at least two students), there are 69 relationships that are not shared with the Wikipedia (as mentioned in Table 5.4). Among these non-shared 69 relationships the most frequently mentioned five relationships, based on frequencies shown in Table 3.9, are family↔friendship (15), friendship↔school (10), school↔work (9), joy↔sorrow (7) and friendship↔hobby (6), so thus we think that even if connectivity between these concepts seems to have been considered important for students in their concept maps, their corresponding connectivity has not however emerged into hyperlink network of the Wikipedia during its collaborative building process.

We wanted to get better understanding about how students in a real educational setting traverse intuitively in hyperlink network of the Wikipedia and we wanted to try to identify some typical characteristics in associative conceptual chains in exploration paths. Especially we wanted to carry out experiments with students to verify suggested benefits of our proposed method to support educational exploration in conceptual network based on hyperlink network of the Wikipedia. To achieve this goal we carried out two supplementary experimental analysis that are discussed in detail in Chapter 10. In Subchapter 10.2 we describe and analyze results of our experiment concerning *recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network*

after exploration task. In Subchapter 10.3 we describe and analyze results of our experiment concerning *recall of shown hyperlinks forming the shortest paths in hyperlink network after exploration task.*

During the first supplementary experiment, discussed in detail in Subchapter 10.2, besides measuring recall after exploration task we gained from students a collection of traversed exploration paths in hyperlink network and we now provide some analysis about them. To carry out exploration experiment with students in such a hyperlink network that has a sufficient coverage and compactness and that can be conveniently contrasted to our other experimental data about conceptual learning we decided to use such partial segment of the hyperlink network of the Wikipedia that relies on 69 shared concepts.

We carried out in “hyperlink network of 55 concepts” an *exploration task* with 49 students having an average age of 17.4 years (median value 17). In further analysis, discussed in Subchapter 10.2, we refer to this group of students as experiment group (n=49) and full listing of background characteristics of members of experiment group are shown in Appendix X. Please note that the members of this experiment group consist of completely different people than the group of 103 students which was explained in Subchapter 3.9 and also different people than experiment group and control group that were discussed in Subchapter 10.3 (i.e. there is no overlap of persons for these five experimental groups: group of 103 students explained in Subchapter 3.9, experiment group and control group explained in Subchapter 10.2 as well as experiment group and control group explained in Subchapter 10.3).

To ensure comparability of various exploration paths we decided that all exploration paths had to start from concept Human since among 69 shared concepts in hyperlink network of the Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5. It turned out that among 69 shared concepts only 57 concepts remained reachable from concept Human (with one or more intermediate hyperlinks needed to be traversed) if each hyperlink was allowed to be traversed only along its actual traversal direction. Thus twelve concepts had to be excluded from analysis, including Book, Clock, Dream, Ground, Hobby, Hospital, Money, Party, Purpose, Shoe, Sorrow and Summer as well as 20 hyperlinks containing any of these 12 concepts. Since we considered that Atmosphere_of_Earth and Physical_fitness seemed to have some terminological ambiguity, we removed these two concepts from the hyperlink network of 69 shared concepts as well as 16 hyperlinks containing either of these two concepts (11 for Atmosphere_of_Earth and 5 for Physical_fitness). Therefore finally, in *exploration experiment* the students were allowed to browse inside a hyperlink network containing 55 concepts and 212 hyperlinks between them, and we refer to this network in our further analysis with name “*hyperlink network of 55 concepts*”. All these 212 hyperlinks of “hyperlink network of 55 concepts” are connecting 55 concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (55 concepts include concept Human). All these 212 hyperlinks are shown in Appendix J supplied with a relation statement for each hyperlink in English and its Finnish translation.

Please note that even if in Subchapters 5.3–5.4 vocabulary sizes of 102, 69 and 55 seem to offer relatively low sample sizes for analysis, we have explained in Subchapter 3.10 (and originally in publication [P9]) how they still can offer relatively good coverage. Thus since it has been suggested that 95-percent-level comprehension can be achieved with a vocabulary of just 2000–3000 word families ((Nation & Waring 1997) referring to (Laufer 1989)), among 2000-3000 highest-ranking concepts of British National Corpus (provided by Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>)) 102 highest-ranking nouns represented 5.8–6.0 percent (among concepts of any world class) or 27–29 percent (among nouns), and 55 highest-ranking nouns represented 1.0–1.1 percent (among concepts of any world class) or 4.8–5.2 percent (among nouns). Furthermore these vocabularies of 102, 69 and 55 nouns were based on 102 highest-ranking nouns generated by students (n=103) so that the set of 102 nouns represented 60 percent of noun usage of students and the set of 55 nouns represented 43 percent of noun usage of students (as we explained in Subchapter 3.10 (and originally in publication [P9])).

Relation statements have been extracted from a Wikipedia article of start concept, primarily taken from the text surrounding the hyperlink anchor of the currently observed hyperlink pointing to the end concept, but possibly with some modifications. In relation statements the start concept and the end concept can be in various conjugated forms and thus not necessarily as nouns although a noun form can be considered preferable in most cases for clarity. Please note that due to lack of suitable sentence surrounding the hyperlink anchor of the start concept of a hyperlink, some of the relation statements are generated and synthesized based on other contextual text segments we identified relatively near the hyperlink anchor or possibly based on a relation statement we managed to identify for another hyperlink going in the opposite direction (i.e. for a hyperlink whose start concept is the end concept of current hyperlink and the end concept is the start concept of current hyperlink). In Appendix J it is mentioned which relation statements have been generated and synthesized with this special method.

Appendix Y lists for each member of this experiment group concepts actively selected by student during exploration task. Although we present here the results in English, the exploration task was carried out in Finnish based on Finnish translations of all 212 hyperlinks shown in Appendix J supplied with a relation statement for each hyperlink. An important characteristic to note is that in exploration experiment each student had to traverse exactly twenty hyperlinks (i.e. to take 20 steps) in “hyperlink network of 55 concepts” and for each student each hyperlink belonging to “hyperlink network of 55 concepts” was allowed to be traversed at most once. So when starting exploration task the student had 212 different hyperlinks available to be traversed at some point of experiment but always when traversing any hyperlink in the “hyperlink network of 55 concepts” this traversed hyperlink was removed from the original collection of available hyperlinks thus reducing traversable hyperlinks one by one. Thus even if the student’s exploration path leads to an already earlier visited concept in the “hyperlink network of 55 concepts” this concept no longer shows those hyperlinks that the student has already traversed when departing this concept earlier in exploration.

However, an exceptional case is if the student’s exploration reaches a dead-end, i.e. the student arrives to a concept that does not offer (at least anymore) any departing hyperlinks to be traversed next, and in this case the student is exceptionally provided with a sufficient series of non-branching hyperlinks that enable her to *roll back exploration* to the most previous point in her exploration path history that still offers traversable departing hyperlinks. There are altogether 14 roll back hyperlinks (shown in Appendix J) that supplement 212 hyperlinks of “hyperlink network of 55 concepts”. Table 5.10 illustrates an example of three consecutive steps of exploration in “hyperlink network of 55 concepts” when a student performs exploration task.

Appendix K shows the number of traversals made by students for some of the highest-ranking traversed hyperlinks in this network of 212 hyperlinks, number of traversals are shown for all students (n=49) and also separately for male students (n=18) and female students (n=31). Appendix K also shows how many alternative hyperlinks were available when the student decided to select each hyperlink. 164 hyperlinks of these 212 available hyperlinks (164/212 is about 0.774 thus meaning about 77.4 percent) became explored by students in exploration task starting from concept Human. There were five concepts of 55 concepts that did get during exploration zero departures and zero arrivals (Cat, Computer, Dog, Pet and Telephone).

Table 5.10. Illustration of an example of three consecutive steps of exploration in “hyperlink network of 55 concepts” when student performs exploration task. This sample is based on full listing of hyperlinks shown in Appendix J.

<p>Step 1. <i>Student has arrived to concept Friendship and three hyperlinked concepts, indicated here with underlining, are shown supplied with following relation statements in which the current concept is indicated with cursive formatting:</i></p> <ul style="list-style-type: none"> - <i>friendships</i> are often the most important human relationships of the emotional life in <u>adolescence</u> - in interpersonal relationships <i>friendships</i> are found also among <u>animals</u> with high intelligence - concerning <i>friendship love</i> is above all other motives as an inspiration <p><i>Student decides to traverse hyperlink leading to Love.</i></p>
<p>Step 2. <i>Student has arrived to concept Love and six hyperlinked concepts are shown supplied with following relation statements:</i></p> <ul style="list-style-type: none"> - according to <u>biology</u> there are two major drives in <i>love</i>: sexual attraction and attachment - <i>love</i> can describe an intense feeling of affection, an <u>emotion</u> or an emotional state - <i>love</i> has many different meanings ranging to something one would die for, like <u>family</u> - concerning <i>love friendship</i> means the spirit between friends - <i>love</i> is connected to emotions about <u>happiness</u> - throughout history, philosophy and <u>religion</u> have done the most speculation on the phenomenon of <i>love</i> <p><i>Student decides to traverse hyperlink leading to Friendship.</i></p>
<p>Step 3. <i>Student has arrived again to concept Friendship and now two hyperlinked concepts are shown supplied with following relation statements, i.e. hyperlink to Love traversed last time is not anymore traversable and has been removed:</i></p> <ul style="list-style-type: none"> - <i>friendships</i> are often the most important human relationships of the emotional life in <u>adolescence</u> - in interpersonal relationships <i>friendships</i> are found also among <u>animals</u> with high intelligence <p><i>Student decides to traverse hyperlink leading to Adolescence, etc.</i></p>

Among these 164 explored hyperlinks some of the *most actively traversed hyperlinks* are shown in Table 5.11. In the table the number of traversals for such hyperlinks that depart from concept Human can be influenced by the fact that in the exploration experiment students had to start always from concept Human, however in parenthesis is shown the number of traversals when excluding those traversals that happened during starting from concept Human. Table 5.11 also shows for each hyperlink the average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink (for hyperlinks departing from concept Human, indicated with an asterisk (*), the average number of selectable alternative hyperlinks is calculated only based on those traversals when excluding starting from concept Human). Showing this average number of selectable alternative hyperlinks aims to offer a some kind of possibility to judge if a high number of traversals for a hyperlink is related to having a small number of selectable hyperlinks in traversals just preceding traversing current hyperlink which could indicate that popularity of current hyperlink can be induced by some kind of bottleneck and not so much motivated by active selections by student. Thus for example even if hyperlink Emotion → Love has got the second-highest-ranking position in Table 5.11 with 26 traversals among all students it turns out that relatively low value of the average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink (1.846154) seem to indicate that the popularity of traversing hyperlink Emotion → Love might be partly contributed by limited number of alternative paths available before arriving to concept Emotion.

Besides 212 above mentioned hyperlinks the students were allowed to explore still additional *14 hyperlinks that were traversed to roll back* to previously visited concept when the student's exploration had led to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration. Among these 14 additional hyperlinks, which are shown in Appendix J, three most actively traversed ones by all students were: Experience → Emotion (18 traversals), Experience → Learning (8 traversals) and Joy → Emotion (7 traversals).

Table 5.11. Some of the highest-ranking traversed hyperlinks in “hyperlink network of 55 concepts” in exploration paths of students (n=49), shown for all students and also separately for male students and female students (full listing is available in Appendix K).

<i>All students participating in exploration task (n = 49)</i>			<i>All male students participating in exploration task (n = 18)</i>		<i>All female students participating in exploration task (n = 31)</i>	
<i>Traversed hyperlink (current hyperlink)</i>	<i>Number of traversals</i>	<i>Average number of selectable alternative hyperlinks shown to student when she selected to traverse a hyperlink that was just before traversing current hyperlink</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>
Happiness -> Emotion	29	3.758621	Animal -> Nature	4	Happiness -> Emotion	25
Emotion -> Love	26	1.846154	Joy -> Happiness	4	Emotion -> Love	23
Joy -> Happiness	24	2.125	Happiness -> Joy	4	Disease -> Death	22
Disease -> Death	24	4.625	Happiness -> Emotion	4	Joy -> Happiness	20
Happiness -> Joy	21	4.285714	Sun -> Oxygen	3	Adolescence -> Education	17
Human -> Diet_(nutrition)	19 (2*)	5.5*	Sun -> Plant	3	Happiness -> Joy	17
Emotion -> Experience	19	7.263158	Biology -> Animal	3	Human -> Diet_(nutrition)	16
Experience -> Emotion (only to roll back)	18	3.833333	Organism -> Biology	3	Emotion -> Experience	16
Organism -> Biology	17	5.176471	Organism -> Plant	3	Experience -> Emotion (only to roll back)	15
Adolescence -> Education	17	6.764706	Organism -> Heart	3	Organism -> Biology	14
Love -> Friendship	16	2.75	Oxygen -> Sun	3	Education -> Learning	14
Education -> Learning	14	3.428571	Oxygen -> Plant	3	Learning -> Education	14
Learning -> Education	14	5.642857	Oxygen -> Water	3	Love -> Friendship	14
Emotion -> Happiness	14	3.571429	Human -> Diet_(nutrition)	3	Family -> Mother	12
Family -> Mother	13	8.384615	Plant -> Nature	3	Health -> Disease	12
Diet_(nutrition) -> Health	13	14.92308	Plant -> Tree	3	Diet_(nutrition) -> Health	11
Health -> Disease	13	10.38462	Experience -> Emotion (only to roll back)	3	Emotion -> Happiness	11
Love -> Happiness	11	6.363636	Happiness -> Love (only to roll back)	3	Emotion -> Joy	10
Emotion -> Joy	11	2.090909	Love -> Happiness	3	Friendship -> Adolescence	10
Love -> Emotion	10	5.4	Emotion -> Experience	3	Biology -> Nature	9
Friendship -> Adolescence	10	5.3	Emotion -> Happiness	3	Human -> Adolescence	9
			Emotion -> Love	3	Adolescence -> Child	9
					Love -> Emotion	9

Appendix L shows, based on Appendix K, the *most actively traversed departing and arriving hyperlinks* for each of 55 concepts in “hyperlink network of 55 concepts”. Relying on Appendix L Figure 5.6 visualizes the most actively traversed departing and arriving hyperlinks in “hyperlink network of 55 concepts” (explained originally in publication [P9]).

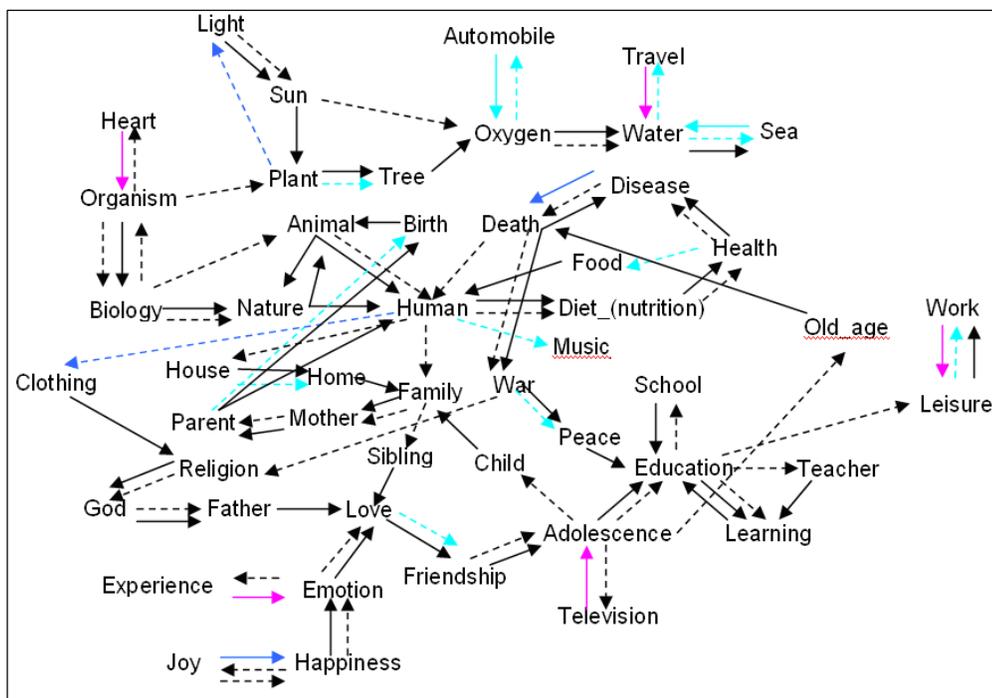


Figure 5.6 (originally published as Figure 1b in publication [P9]). The most actively traversed departing and arriving links in “hyperlink network of 55 concepts” are illustrated so that solid lines indicate departing links and dotted lines arriving links (n=49). If several links share the position as the most active link they all are included in the figure as parallel links (for example both links Animal → Human and Death → Human arrive at concept Human). Five links having pink color indicate traversed links that are not in original “hyperlink network of 55 concepts” but are needed to roll back in case of encountering a dead end in exploration. Turquoise and blue lines indicate that surfing occurred along the sole connecting arriving/departing link between these two concepts (i.e. no alternative routes were available), turquoise links were inherently sole connecting links whereas blue links emerged as sole connecting links after roll back links had been excluded between these two concepts. Among all 55 concepts five concepts did not have any traversed arriving/departing linking, including Cat, Computer, Dog, Pet and Telephone, and concept Music had only traversed arriving link and not departing link.

Table 5.12 shows in “hyperlink of 55 concepts” for each concept the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths so that occurrences are counted separately for traversed hyperlinks and departures from a concept.

We think that various forms of interactive and engaging learning activities can be developed based student’s exploration in hyperlink network. To illustrate pedagogic potential of *associative chaining* of browsed concepts and relation statements in exploration paths we generated examples based on Figure 5.6. An exploration path starting from concept Human and proceeding the *most actively traversed departing hyperlinks* in “hyperlink network of 55 concepts” generates following *learning path*:

Human → Diet_(nutrition) → Health → Disease → Death → War → Peace →
Education → Learning → Education (and then remaining in an eternal cycle
Education → Learning → Education → etc.)
(originally published as Figure 2a in publication [P9])

When chaining relation statements of each of these hyperlinks (shown in Appendix J) we gain a following *educational story* (start concept of hyperlink indicated with italics and end concept of hyperlink with underlining)¹⁷:

Concerning *humans* body size is significantly influenced by environmental factors such as diet.
Dietary habits and choices play a significant role in health.
Health is a state of complete well-being and not merely the absence of disease.
Disease is often used to refer to a uncomfortable condition possibly leading to death.
War can be considered as a situation whereby *death* assumes absolute value.
Theories of *war* must explain also peace.
Peaceful development can be a set of many different elements such as education.
Education encompasses teaching and learning specific skills.
Learning is the goal of education.
(originally published as Figure 2a in publication [P9])

We think that even if having somewhat limited scope, already these examples show that suggested method of traversing exploration paths can offer to the student a relatively intuitive way to adopt step by step new pieces of knowledge in a simple process. Relying on exploration experiment with 49 students this exploration path can be considered to represent some kind of average association chain of students about gradually evolving thinking when starting from concept Human and finally reaching limits of this expansion when arriving to a repeating cycle. We believe that with sufficiently large and diverse collection of traversed exploration paths a student can achieve relatively extensive coverage of hyperlink network of concepts about desired learning topic. We think that this gained collection of exploration paths can offer interesting insight to the student's conceptualization and personal characteristics as well as to the semantical properties of language and consciousness.

¹⁷ In the shown educational story the relation statements for hyperlinks Diet->Health and Peace->Education illustrate that in relation statements start concept and end concept can be in various conjugated forms.

Table 5.12. In "hyperlink of 55 concepts" for each concept the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths so that occurrences are counted separately for traversed hyperlinks and departures from a concept.

55 concepts reachable in exploration from concept Human in "hyperlink network of 55 concepts"	In "hyperlink network of 55 concepts" (belonging to hyperlink network of the Wikipedia)		In exploration paths that students (n=49) traverse in "hyperlink network of 55 concepts" (belonging to hyperlink network of the Wikipedia)			
	as a start concept for how many hyperlinks	as an end concept for how many hyperlinks	as a start concept for how many traversed hyperlinks	as an end concept for how many traversed hyperlinks	in exploration how many departures from this concept	in exploration how many arrivals to this concept
Adolescence	4	6	4	5	33	31
Animal	7	8	5	6	18	19
Automobile	1	1	1	1	2	2
Biology	6	9	6	6	32	33
Birth	4	1	3	1	5	5
Cat	3	2	0	0	0	0
Child	6	5	5	3	17	17
Clothing	2	1	2	1	3	3
Computer	2	1	0	0	0	0
Death	7	5	6	4	35	31
Diet (nutrition)	4	4	4	2	23	23
Disease	1	4	1	4	24	27
Dog	3	2	0	0	0	0
Education	10	6	8	6	45	46
Emotion	4	3	4	3	70	48
Experience	0	2	0	2	0	27
Family	5	10	5	8	34	35
Father	5	5	5	4	12	13
Food	10	1	1	1	1	1
Friendship	3	1	3	1	14	16
God	3	2	1	1	5	5
Happiness	2	4	2	4	50	55
Health	4	4	4	3	23	23
Heart	0	3	0	3	0	15
Home	3	1	1	1	2	2
House	4	2	1	1	2	2
Human	16	11	14	9	80	36
Joy	1	2	1	2	24	32
Learning	2	2	2	2	22	20
Leisure	5	4	5	3	14	11
Light	2	1	2	1	7	6
Love	6	7	5	6	50	48
Mother	7	5	4	4	17	17
Music	2	1	0	1	0	1
Nature	7	4	6	3	20	21
Old age	4	3	2	2	4	5
Organism	3	7	3	6	34	29
Oxygen	6	9	6	9	26	26
Parent	6	4	6	4	17	17
Peace	2	1	2	1	8	8
Pet	3	3	0	0	0	0
Plant	8	8	8	6	31	32
Religion	3	7	3	4	10	10
School	2	3	2	2	10	11
Sea	1	1	1	1	7	7
Sibling	5	7	3	5	12	13
Sun	2	6	2	5	14	17
Teacher	3	2	3	2	12	9
Telephone	0	1	0	0	0	0
Television	0	7	0	4	0	7
Travel	0	1	0	1	0	3
Tree	2	1	2	1	7	7
War	3	4	3	3	15	15
Water	8	6	7	5	23	22
Work	0	1	0	1	0	5
<i>Sum</i>	212	212	164	164	914	914
<i>Average</i>	3.85	3.85	2.98	2.98	16.62	16.62
<i>Median</i>	3	3	2	3	12	15

We think that in hyperlink network those concepts that belong to repeating cycle that define limits to expansion of exploration path may indicate some essential properties about semantics and how conceptualization inherently emerges in human mind. Since our research focuses on education and learning we find it fascinating that just shown example of exploration path starting from concept Human happens to finally arrive to a repeating cycle that contains concepts Education and Learning. Also in our later analysis discussed in Subchapter 6.3 we encountered similar feature of arriving to a repeating cycle. We suggest that this process of arriving to a repeating cycle that we have identified in the Wikipedia (which holds small-world properties (Ingawale et al. 2009)) is related to previous findings of Kinouchi et al. (2002) that a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step). Naturally it can be possible to purposefully avoid entering an eternal cycle in exploration so that when arriving again to a previously visited concept now the learner chooses the second-highest-ranking concept (if available) instead of the highest-ranking concept to proceed next and thus a new branching emerges to traversed path enabling continuing exploration along yet unexplored hyperlinks.

Different perspectives can be achieved if exploration path proceeds a chain of arriving links instead of departing links. An exploration path starting from concept Human and proceeding the *most actively traversed arriving hyperlinks* in “hyperlink network of 55 concepts” generates two alternative *learning paths* since it appears that there are two most actively traversed arriving links arriving to concept Human that share the highest ranking and thus two different paths emerge proceeding to Death or Animal.

One of these two paths is:

Human ← Death ← Disease ← Health ← Diet_(nutrition) ← Human (and then again possibility to proceed to Death or Animal, i.e. leading to consecutive cycles that arrive back to Human or then leading to a path proceeding through concept Animal as explained next)
(originally published as Figure 2a in publication [P9])

The other one of two paths is:

Human ← Animal ← Biology ← Organism ← Biology (and then remaining in an eternal cycle Biology ← Organism ← Biology ← etc.)
(originally published as Figure 2a in publication [P9])

These just shown learning paths can be contrasted with a learning path generated based on the highest-ranking relationships in concept maps drawn by students (n=103) mentioned by at least two students (based on Table 3.9) and considering only those relationships that contain concepts belonging to 55 concepts of “hyperlink network of 55 concepts”. When traversing *relationships of concept maps* (linking direction was not specified in relationships of concept maps) so that we start from concept “human” and

proceed at each step to relationship that has highest number of occurrences we get a learning path:

human=family=friend=school=work=education=school (and then again possibility to proceed to work and so on thus forming an eternal cycle)
(originally published as Figure 2a in publication [P9])

When comparing learning path generated based on relationships of concept maps with learning path generated based on “hyperlink network of 55 concepts” (explained originally in publication [P9]) it seems that learning path based on relationships of concept maps focuses on social themes whereas learning path based on “hyperlink network of 55 concepts” focuses on survival themes. Anyway, interestingly learning paths based on concept maps and “hyperlink network of 55 concept” with departing hyperlinks finally arrive to an eternal cycle having a shared theme concerning education. Further experiments with much bigger samples are needed to make more accurate estimates.

In respect to traversing exploration paths in networks shown in Figure 5.6 it could be also possible to select paths so that highest-ranking concept based on various properties (for example the number of occurrences as start concept or end concept in hyperlinks as well as the number of occurrences in exploration paths, as shown in Table 5.12) could be prioritized even when having distance longer than just one hyperlink. Therefore each concept could be considered metaphorically to have some kind of own gravitational field and the sum of all these gravitational fields would then contribute to selecting at each step the next hyperlink to be traversed next in the hyperlink network.

5.4. Comparison between patterns of exploration and structure of hyperlink network

Based on Table 5.12 for each of five comparison tests, Table 5.13 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of departures from a concept during exploration in the “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in the “hyperlink network of 55 concepts” (explained originally in publication [P9]).

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.13 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of departures from a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as a start

concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.5. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.13. Degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of departures from a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.3233 (null hypothesis Hks not rejected)	gamma=0.4839216 (standard error 0.1817563); null hypothesis Hgk rejected (p=0.007756853)	rho=0.5741486; null hypothesis Hsr rejected (p=4.581×10 ⁻⁶)	tau=0.4512068; null hypothesis Hkr rejected (p=5.481×10 ⁻⁶)

Based on Table 5.12 for each of five comparison tests Table 5.14 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of p<0.05 when estimating degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (explained originally in publication [P9]).

Table 5.14. Degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	p=0.7877 (null hypothesis Hst not rejected)	p=0.1458 (null hypothesis Hks not rejected)	gamma=0.5606661 (standard error 0.1729323); null hypothesis Hgk rejected (p=0.001186469)	rho=0.6928744; null hypothesis Hsr rejected (p=4.585×10 ⁻⁹)	tau=0.5174761; null hypothesis Hkr rejected (p=1.78×10 ⁻⁷)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.14 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.6. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Based on Table 5.12 for each of five comparison tests Table 5.15 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (explained originally in publication [P9]).

Table 5.15. Degrees of dependency between the number of departures from a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of departures from a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	p=0.8899 (null hypothesis Hst not rejected)	p=0.01904 (null hypothesis Hks rejected)	gamma=0.5487013 (standard error 0.1766411); null hypothesis Hgk rejected (p=0.001894411)	rho=0.6736606; null hypothesis Hsr rejected (p=1.737×10 ⁻⁸)	tau=0.5017701; null hypothesis Hkr rejected (p=5.435×10 ⁻⁷)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.15 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of departures from a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled

frequency distribution of number of different hyperlinks that a concept occurs as an end concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.4. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Based on Table 5.12 for each of five comparison tests Table 5.16 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (explained originally in publication [P9]).

Table 5.16. Degrees of dependency between the number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” and the number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (n=49).

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolmogorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” (scaled)	number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” (scaled)	$p=1$ (null hypothesis Hst not rejected)	$p=0.3233$ (null hypothesis Hks not rejected)	$\text{gamma}=0.3266564$ (standard error 0.1945546); null hypothesis Hgk not rejected ($p=0.09315289$)	$\text{rho}=0.4050271$; null hypothesis Hsr rejected ($p=0.002159$)	$\text{tau}=0.3057519$; null hypothesis Hkr rejected ($p=0.001857$)

To facilitate identifying possible similarities between frequency distributions of Table 5.12 we transformed for representation of Table 5.16 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of arrivals to a concept during exploration in “hyperlink network of 55 concepts” has a weighting parameter 1 and scaled frequency distribution of number of different hyperlinks that a concept occurs as a start concept for these hyperlinks in “hyperlink network of 55 concepts” has a weighting parameter 3.6. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 5.17 shows some of the greatest ranking concepts from Table 5.12 in respect to start and end concepts in hyperlinks and departures and arrivals relating to them (explained originally in publication [P9]). Based on pair-wise comparison of columns 2

and 4 and columns 3 and 5 in Table 5.12 we wanted to identify every such concept that had a rich variety of departing and arriving hyperlinks which all still became traversed in exploration task, thus indicating a specifically favored concept. Therefore we defined a criterion to find concepts that had at least two departing and two arriving hyperlinks in “hyperlink network of 55 concepts” and all of their arriving and departing hyperlinks became traversed at least by one student during exploration task. We managed to find six concepts meeting this criterion concerning favoured concept: Oxygen (6 departing and 9 arriving hyperlinks), Parent (6 departing and 4 arriving hyperlinks), Emotion (4 departing and 3 arriving hyperlinks), Happiness (2 departing and 4 arriving hyperlinks), Teacher (3 departing and 2 arriving hyperlinks) and Learning (2 departing and 2 arriving hyperlinks).

Table 5.17. Some of the greatest ranking concepts from Table 5.12 in respect to start and end concepts in hyperlinks and departures and arrivals relating to them.

In “hyperlink network of 55 concepts” (belonging to hyperlink network of the Wikipedia)		In exploration paths that students (n=49) traverse in “hyperlink network of 55 concepts” (belonging to hyperlink network of the Wikipedia)			
Some of the greatest ranking start concepts for hyperlinks (occurrences)	Some of the greatest ranking end concepts for hyperlinks (occurrences)	Some of the greatest ranking start concepts for traversed hyperlinks (occurrences)	Some of the greatest ranking end concepts for traversed hyperlinks (occurrences)	Some of the concepts having greatest number of departures (occurrences)	Some of the concepts having greatest number of arrivals (occurrences)
Human (16)	Human (11)	Human (14)	Human; Oxygen (9)	Human (80)	Happiness (55)
Education; Food (10)	Family (10)	Education; Plant (8)	Family (8)	Emotion (70)	Emotion; Love (48)
Plant; Water (8)	Biology; Oxygen (9)	Water (7)	Animal; Biology; Education; Love; Organism; Plant (6)	Happiness; Love (50)	Education (46)

Table 5.18 shows occurrences of *encountered and revisited concepts in exploration paths* among 55 concepts reachable in exploration from concept Human in “hyperlink network of 55 concepts” (case of encountered concepts in exploration paths was explained originally in publication [P9]). For each student each concept in counted at most once. Concept Human was not counted when exploration started from it but if exploration later arrived to concept Human it was then counted. The numbers of encountered concepts can be contrasted with notion that statistically all 49 students together made $49 \times 20 = 980$ encounters with concepts which means that they should make on average $980/55 = 17.8$ encounters per each of 55 concepts belonging to “hyperlink network of 55 concepts”. Similarly for 18 male students should make on average 7.3 encounters per each of 55 concepts, and 31 female students on average 11.3 encounters per each of 55 concepts. Thus in Table 5.18 in six first columns can be seen that concepts that receive occurrences above just mentioned average values can be considered to have been specifically favored in exploration by all students, male students and female students, respectively.

Table 5.18 part 1 of 2 (starts here and continues on next page). Occurrences of encountered and revisited concepts in exploration paths (n=49) among 55 concepts reachable in exploration from concept Human in “hyperlink network of 55 concepts”.

Encountered concepts in exploration paths when each concept counted at most once for each student						Revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student					
All students (n=49)		Male students (n=18)		Female students (n=31)		All students (n=49)		Male students (n=18)		Female students (n=31)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Love	30	Human	12	Emotion	22	Emotion	23	Death	6	Emotion	17
Emotion	28	Diet_(nutrition)	9	Love	22	Love	17	Emotion	6	Love	13
Human	28	Animal	8	Adolescence	20	Education	16	Happiness	6	Education	11
Experience	26	Biology	8	Happiness	19	Happiness	15	Organism	6	Happiness	9
Happiness	26	Death	8	Experience	18	Death	12	Education	5	Biology	7
Adolescence	25	Disease	8	Family	17	Learning	10	Water	5	Learning	7
Biology	23	Experience	8	Education	16	Plant	10	Love	4	Death	6
Family	23	Love	8	Human	16	Biology	9	Oxygen	4	Family	6
Education	22	Organism	8	Biology	15	Organism	9	Plant	4	Plant	6
Death	21	Oxygen	8	Death	13	Water	9	Sun	4	Human	5
Organism	21	Plant	8	Organism	13	Human	8	Adolescence	3	Joy	5
Diet_(nutrition)	20	Happiness	7	Disease	12	Joy	8	Diet_(nutrition)	3	Leisure	5
Disease	20	Health	7	Friendship	12	Disease	7	Disease	3	Disease	4
Health	19	Joy	7	Health	12	Family	7	Human	3	Water	4
Joy	19	Nature	7	Joy	12	Oxygen	7	Joy	3	Adolescence	3
Animal	17	Sun	7	Mother	12	Adolescence	6	Learning	3	Health	3
Parent	17	Education	6	Child	11	Leisure	6	Biology	2	Nature	3
Plant	17	Emotion	6	Diet_(nutrition)	11	Sun	5	Animal	1	Organism	3
Child	16	Family	6	Learning	11	Health	4	Clothing	1	Oxygen	3
Friendship	16	Heart	6	Parent	11	Nature	4	Family	1	Teacher	2
Nature	16	Parent	6	Animal	9	Diet_(nutrition)	3	Father	1	Animal	1
Oxygen	16	Religion	6	Heart	9	Teacher	3	Health	1	Child	1
Heart	15	War	6	Nature	9	Animal	2	Leisure	1	Experience	1

Table 5.19 shows ranking of 55 concepts of “hyperlink network of 55 concepts” in respect to four characteristics: encountered concepts in exploration (based on Table 5.18), sum of departures and arrivals in exploration (based on Table 5.12), occurrences in word lists of students (based on Table 3.4) and sums of measures of importance given by each student (based on Table 3.4). To facilitate pair-wise comparison of rankings the ranking values are transformed to an equal ranking scale 1–55.

Based on Table 5.19 for each of three comparison tests Table 5.20 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between four rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration,

sum of departures and arrivals in exploration, occurrences in word lists of students and sums of measures of importance given by each student (case of occurrences in word lists of students compared to encountered concepts in exploration paths and case of sums of measures of importance given by each student compared to encountered concepts in exploration paths were explained originally in publication [P9]).

Table 5.18 part 2 of 2 (started on previous page and continues here).

Encountered concepts in exploration paths when each concept counted at most once for each student						Revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student					
All students (n=49)		Male students (n=18)		Female students (n=31)		All students (n=49)		Male students (n=18)		Female students (n=31)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
Learning	15	Water	6	Plant	9	Father	2	Light	1	Father	1
Mother	15	Adolescence	5	Sibling	9	Mother	2	Mother	1	Mother	1
War	13	Child	5	Leisure	8	School	2	Nature	1	School	1
Sibling	12	Peace	5	Oxygen	8	War	2	School	1	Sun	1
Father	11	Father	4	Father	7	Child	1	Sibling	1	War	1
Sun	11	Friendship	4	War	7	Clothing	1	Teacher	1	Automobile	0
Water	11	Learning	4	School	6	Experience	1	War	1	Birth	0
Leisure	10	Teacher	4	Birth	5	Light	1	Automobile	0	Cat	0
Religion	10	Tree	4	Teacher	5	Sibling	1	Birth	0	Clothing	0
School	9	Light	3	Water	5	Automobile	0	Cat	0	Computer	0
Teacher	9	Mother	3	Old_age	4	Birth	0	Child	0	Diet (nutrition)	0
Peace	8	School	3	Religion	4	Cat	0	Computer	0	Dog	0
Sea	7	Sea	3	Sea	4	Computer	0	Dog	0	Food	0
Television	7	Sibling	3	Sun	4	Dog	0	Experience	0	Friendship	0
Tree	7	Television	3	Television	4	Food	0	Food	0	God	0
Light	6	Automobile	2	Work	4	Friendship	0	Friendship	0	Heart	0
Birth	5	Clothing	2	God	3	God	0	God	0	Home	0
God	5	God	2	Light	3	Heart	0	Heart	0	House	0
Old_age	5	Leisure	2	Peace	3	Home	0	Home	0	Light	0
Work	5	Travel	2	Tree	3	House	0	House	0	Music	0
Clothing	3	Home	1	Clothing	1	Music	0	Music	0	Old_age	0
Travel	3	House	1	Food	1	Old_age	0	Old_age	0	Parent	0
Automobile	2	Music	1	Home	1	Parent	0	Parent	0	Peace	0
Home	2	Old_age	1	House	1	Peace	0	Peace	0	Pet	0
House	2	Work	1	Travel	1	Pet	0	Pet	0	Religion	0
Food	1	Birth	0	Automobile	0	Religion	0	Religion	0	Sea	0
Music	1	Cat	0	Cat	0	Sea	0	Sea	0	Sibling	0
Cat	0	Computer	0	Computer	0	Telephone	0	Telephone	0	Telephone	0
Computer	0	Dog	0	Dog	0	Television	0	Television	0	Television	0
Dog	0	Food	0	Music	0	Travel	0	Travel	0	Travel	0
Pet	0	Pet	0	Pet	0	Tree	0	Tree	0	Tree	0
Telephone	0	Telephone	0	Telephone	0	Work	0	Work	0	Work	0

Table 5.19 part 1 of 2 (starts here and continues on next page). Ranking of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration, sum of departures and arrivals in exploration, occurrences in word lists of students and sums of measures of importance given by each student, transformed to equal ranking scale 1–55. A special case for ranking comparison are concepts that did not become encountered in exploration (Cat, Dog, Computer, Pet and Telephone), indicated with an asterisk (*).

55 concepts (common nouns) in conceptual structures	Ranking values transformed to equal scale 1–55 (how many positions higher than ranking of encountered concepts in exploration)			
Concept as a Wikipedia article title (<i>corresponding concept as generated by students if not the same concept</i>)	Encountered concepts in exploration (all 49 explorations) (n=49)	Sum of departures and arrivals in exploration (all 49 explorations) (n=49)	Occurrences in word lists of students (n=103)	Sums of measures of importance given by each student (n=103)
Love	1	4 (-3)	5.5s (-4.5s)	3 (-2)
Emotion	2.5s	1 (+1.5s)	40s (-37.5s)	30 (-27.5s)
Human	2.5s	2 (+0.5s)	10 (-7.5s)	9 (-6.5s)
Experience	4.5s	27 (-22.5s)	40s (-35.5s)	40 (-35.5s)
Happiness	4.5s	3 (+1.5s)	24s (-19.5s)	18 (-13.5s)
Adolescence (<i>young (person)</i>)	6	9 (-3)	45s (-39s)	53 (-47)
Biology	7.5s	8 (-0.5s)	45s (-37.5s)	49 (-41.5s)
Family	7.5s	6 (+1.5s)	1 (+6.5s)	1 (+6.5s)
Education	9	5 (+4)	19.5s (-10.5s)	19 (-10)
Death	10.5s	7 (+3.5s)	4 (+6.5s)	7 (+3.5s)
Organism	10.5s	10.5s (0s)	51.5s (-41s)	50 (-39.5s)
Diet_ (nutrition) (<i>nutriment</i>)	12.5s	15.5s (-3s)	51.5s (-39s)	43 (-30.5s)
Disease	12.5s	14 (-1.5s)	40s (-27.5s)	54 (-41.5s)
Health	14.5s	15.5s (-1s)	19.5s (-5s)	14 (+0.5s)
Joy	14.5s	12 (+2.5s)	15s (-0.5s)	17 (-2.5s)
Animal	17s	20 (-3s)	9 (+8s)	12 (+5s)
Parent	17s	22s (-5s)	51.5s (-34.5s)	36 (-19s)
Plant	17s	10.5s (+6.5s)	22 (-5s)	21 (-4s)
Child	20.5s	22s (-1.5s)	15s (+5.5s)	16 (+4.5s)
Friendship (<i>friend</i>)	20.5s	25.5s (-5s)	2 (+18.5s)	2 (+18.5s)
Nature	20.5s	19 (+1.5s)	12 (+8.5s)	11 (+9.5s)
Oxygen	20.5s	13 (+7.5s)	51.5s (-31s)	35 (-14.5s)
Heart	24s	35 (-11s)	40s (-16s)	33.5s (-9.5s)
Learning	24s	18 (+6s)	28s (-4s)	25 (-1s)
Mother	24s	22s (+2s)	28s (-4s)	22 (+2s)
War	26	25.5s (+0.5s)	45s (-19s)	55 (-29)
Sibling (<i>sister</i>)	27	29s (-2s)	51.5s (-24.5s)	52 (-25)
Father	29s	29s (0s)	34.5s (-5.5s)	24 (+5s)
Sun	29s	24 (+5s)	15s (+14s)	15 (+14s)
Water	29s	17 (+12s)	7.5s (+21.5s)	5 (+24s)
Leisure (<i>freetime</i>)	31.5s	29s (+2.5s)	34.5s (-3s)	28.5s (+3s)
Religion	31.5s	33 (-1.5s)	30.5s (+1s)	42 (-10.5s)
School	33.5s	31.5s (+2s)	5.5s (+28s)	8 (+25.5s)
Teacher	33.5s	31.5s (+2s)	51.5s (-18s)	51 (-17.5s)
Peace	35	34 (+1)	45s (-10s)	37 (-2)

Table 5.19 part 2 of 2 (started on previous page and continues here).

55 concepts (common nouns) in conceptual structures	Ranking values transformed to equal scale 1–55 (how many positions higher than ranking of encountered concepts in exploration)			
Concept as a Wikipedia article title (<i>corresponding concept as generated by students if not the same concept</i>)	Encountered concepts in exploration (all 49 explorations) (n=49)	Sum of departures and arrivals in exploration (all 49 explorations) (n=49)	Occurrences in word lists of students (n=103)	Sums of measures of importance given by each student (n=103)
Sea	37s	36.5s (+0.5s)	40s (-3s)	47 (-10s)
Television	37s	42 (-5s)	28s (+9s)	32 (+5s)
Tree	37s	36.5s (+0.5s)	24s (+13s)	31 (+6s)
Light	39	38 (+1)	34.5s (+4.5s)	38.5s (+0.5s)
Birth	41s	39.5s (+1.5s)	11 (+30s)	10 (+31s)
God	41s	39.5s (+1.5s)	45s (-4s)	45.5s (-4.5s)
Old age (<i>elderness</i>)	41s	41 (0s)	34.5s (+6.5s)	44 (-3s)
Work	41s	44 (-3s)	3 (+38s)	4 (+37s)
Clothing (<i>cloth</i>)	44.5s	43 (+1.5s)	34.5s (+10s)	27 (+17.5s)
Travel	44.5s	48 (-3.5s)	51.5s (-7s)	38.5s (+6s)
Automobile (<i>car</i>)	47s	46s (+1s)	24s (+23s)	33.5s (+13.5s)
Home	47s	46s (+1s)	13 (+34s)	13 (+34s)
House	47s	46s (+1s)	17.5s (+29.5s)	20 (+27s)
Food	49.5s	49 (+0.5s)	7.5s (+42s)	6 (+43.5s)
Music	49.5s	50 (-0.5s)	30.5s (+19s)	28.5s (+21s)
Cat*	53s	53s (0s*)	26 (+27s*)	45.5s (+7.5s*)
Computer*	53s	53s (0s*)	21 (+32s*)	26 (+27s*)
Dog*	53s	53s (0s*)	17.5s (+35.5s*)	23 (+30s*)
Pet*	53s	53s (0s*)	34.5s (+18.5s*)	41 (+12s*)
Telephone* (<i>phone</i>)	53s	53s (0s*)	51.5s (+1.5s*)	48 (+5s*)

Relying on Table 5.19, three tables, Table 5.21, Table 5.22 and Table 5.23, enable to contrast ranking based on encountered concepts in exploration with three rankings: ranking based on sum of departures and arrivals in exploration, ranking based on occurrences in word lists of students and ranking based on sums of measures of importance given by each student. These three tables show for each pair of rankings some of the greatest and smallest ranking differences for concepts among observed 55 concepts (case of occurrences in word lists of students compared to encountered concepts in exploration paths and case of sums of measures of importance given by each student compared to encountered concepts in exploration paths were explained originally in publication [P9]). It seems that concepts having higher ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration include for example natural substances (Water and Oxygen) whereas for example emotional issues have higher ranking for encountered concepts in exploration than for sum of departures and arrivals in exploration.

Table 5.20. Degrees of dependency between four rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to encountered concepts in exploration (n=49), sum of departures and arrivals in exploration (n=49), occurrences in word lists of students (n=103) and sums of measures of importance given by each student (n=103).

Compared pair of distributions		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
encountered concepts in exploration (n=49)	sum of departures and arrivals in exploration (n=49)	gamma=0.8838348 (standard error 0.09177504); null hypothesis Hgk rejected (p=0)	rho=0.9583967; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.8716607; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
encountered concepts in exploration (n=49)	occurrences in word lists of students (n=103)	gamma=0.01615272 (standard error 0.200926); null hypothesis Hgk not rejected (p=0.935926)	rho=0.02128859; null hypothesis Hsr not rejected (p=0.8774)	tau=0.01546115; null hypothesis Hkr not rejected (p=0.8724)
encountered concepts in exploration (n=49)	sums of measures of importance given by each student (n=103)	gamma=0.09065551 (standard error 0.195036); null hypothesis Hgk not rejected (p=0.6420645)	rho=0.1246614; null hypothesis Hsr not rejected (p=0.3645)	tau=0.08908127; null hypothesis Hkr not rejected (p=0.3445)
sum of departures and arrivals in exploration (n=49)	occurrences in word lists of students (n=103)	gamma=0.04046243 (standard error 0.1991854); null hypothesis Hgk not rejected (p=0.839026)	rho=0.08030663; null hypothesis Hsr not rejected (p=0.56)	tau=0.03905802; null hypothesis Hkr not rejected (p=0.683)
sum of departures and arrivals in exploration (n=49)	sums of measures of importance given by each student (n=103)	gamma=0.1208791 (standard error 0.192932); null hypothesis Hgk not rejected (p=0.5309626)	rho=0.1882198; null hypothesis Hsr not rejected (p=0.1688)	tau=0.1196902; null hypothesis Hkr not rejected (p=0.2009)
occurrences in word lists of students (n=103)	sums of measures of importance given by each student (n=103)	gamma=0.7863248 (standard error 0.1222799); null hypothesis Hgk rejected (p=1.271583×10 ⁻¹⁰)	rho=0.9042751; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.7645224; null hypothesis Hkr rejected (p=8.882×10 ⁻¹⁶)

Table 5.21. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus sum of departures and arrivals in exploration (n=49). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for sum of departures and arrivals in exploration than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on sum of departures and arrivals in exploration and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Water	+12s	Experience	-22.5s	Cat*; Computer*; Dog*; Father; Old_age; Organism; Pet*; Telephone*	0s
Oxygen	+7.5s	Heart	-11s	Food; Human; Sea; Tree; War	+0.5s
Plant	+6.5s	Friendship; Parent; Television	-5s	Biology; Music	-0.5s
Learning	+6s	Travel	-3.5s	Light; Peace	+1
Sun	+5s	Adolescence; Love	-3	Automobile; Home; House	+1s
Education	+4	Animal; Diet_(nutrition); Work	-3s	Health	-1s
		Sibling	-2s		

Table 5.22. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus occurrences in word lists of students (n=103). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for occurrences in word lists of students than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for occurrences in word lists of students than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on occurrences in word lists of students and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Food	+42s	Organism	-41s	Joy	-0.5s
Work	+38s	Adolescence; Diet_(nutrition)	-39s	Religion	+1s
Dog*	+35.5s	Biology; Emotion	-37.5s	Telephone*	+1.5s
Home	+34s	Experience	-35.5s	Leisure; Sea	-3s
Computer*	+32s	Parent	-34.5s	God; Learning; Mother	-4s
Birth	+30s	Oxygen	-31s		

Table 5.23. Some of the greatest and smallest ranking differences for concepts in respect to encountered concepts in exploration (n=49) versus measures of importance given by each student (n=103). A special case for ranking comparison are concepts that did not become encountered in exploration, indicated with an asterisk (*).

Some of the greatest ranking differences for concepts having higher ranking position for sums of measures of importance given by each student than for encountered concepts in exploration		Some of the greatest ranking differences for concepts having lower ranking position for sums of measures of importance given by each student than for encountered concepts in exploration		Some of the smallest ranking differences for concepts between ranking based on sums of measures of importance given by each student and encountered concepts in exploration	
<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>	<i>Concept</i>	<i>Ranking difference</i>
Food	+43.5s	Adolescence	-47	Health; Light	+0.5s
Work	+37s	Biology; Disease	-41.5s	Learning	-1s
Home	+34s	Organism	-39.5s	Mother	+2s
Birth	+31s	Experience	-35.5s	Love; Peace	-2
Dog*	+30s	Diet_(nutrition)	-30.5s	Joy	-2.5s
Computer*; House	+27s	War	-29		

It also seems that concepts having higher ranking position for occurrences in word lists of students or for sums of measures of importance given by each student than for encountered concepts in exploration include for example Food, Work and Home, whereas for example Adolescence and Organism have higher ranking for encountered concepts in exploration than for occurrences in word lists of students or for sums of measures of importance given by each student.

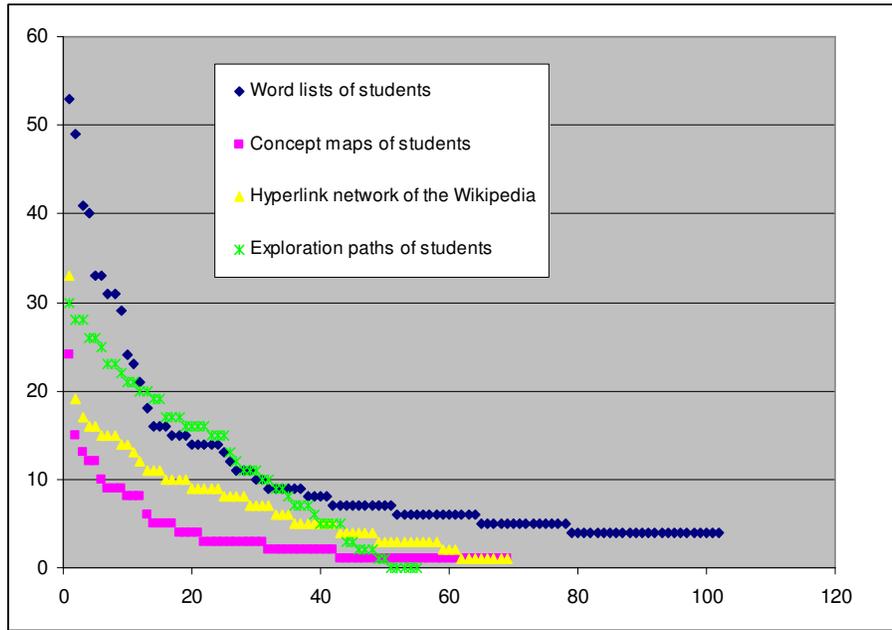


Figure 5.8. Occurrences of concepts a) among 102 core concepts in word lists generated by students mentioned by at least four students ($n=103$) (based on Table 3.4), b) in relationships in concept maps drawn by students ($n=103$) between 69 shared concepts (based on Table 5.5), c) in hyperlink network of Wikipedia between 69 shared concepts (based on Table 5.5), and d) in traversed links in exploration paths of students in “hyperlink network of 55 concepts” when each concept counted at most once for each student ($n=49$) (based on Table 5.18). Each of these four occurrence values on y axis are shown separately in descending order so that while steps on x axis go through concepts one by one these concepts are not processed in same order along x axis for these four parameters and they have only partial overlap due to different vocabulary sizes.

5.5. Findings and their relation to the entity of the dissertation

We think that the proposed method can facilitate pedagogically motivated knowledge management in many ways. The method relies on a constantly growing and collaboratively fine-tuning large online knowledge resource, the Wikipedia. The method supports a learner to explore independently the densely cross-linked pieces of up-to-date knowledge following spontaneously her own educational needs. By extracting conceptual relationships from hyperlinks of the Wikipedia articles the method illustrates intuitively learning paths that can be considered to be the most promising ways to relate concepts in respect to being relying on recommendations given by a diverse community of Wikipedia editors. The learner can build and experiment with compact visualizations that represent her understanding and taken perspectives. Resulting concept maps indicate clearly the relations of facts supporting constructive learning paradigms and creating sustainable customized learning objects. The learning process is inherently self-regulating since previous learning paths and the most probable future directions are efficiently presented and comparable all the time. Evaluating various perspectives with a critical attitude is well supported.

Publication [P2] describes a method that can be used as a standalone application or included into various different types of educational software. The method can be added

as an augmentation to for example the educational framework we described in publication [P1]. Based on promising results in initial experiments, after publication of the publication [P2] we have carried out wider empirical user testing in collaborative environment which seems to have provided increased possibilities for understanding properties of the proposed method. Besides text, the concept maps could be easily transformed to exploit multimedia content. In addition, various metrics could be applied to assist the learner to identify the most mature and trusted content in the online knowledge resource. Thus the method could promote using the most extensive and reliable learning paths.

Proceeding in the learning content space can be performed with manageable steps in abstraction level and minimizing excessive cognitive load. All concept maps built by an individual learner can be agglomerated to greater entities and used as customized learning objects. The method is flexible since it can be applied equally well to exploring details of a specific domain or to ideation of distant associations. The method addresses typical requirements for creative problem solving providing surprising viewpoints yet enabling sustainable continuity to old knowledge. Indeed the functioning of the method described in [P2] gets extended value by various approaches that are introduced in publications [P3] and [P4]. [P3] introduces using statistics about Wikipedia articles to offer additional analysis to assist meaningful browsing in knowledge structures and [P4] introduces possibility to exploit educationally observation of parallel learning paths and temporal versions of knowledge structures. Publication [P5] introduces wiki architecture to manage collections of educational knowledge with collectively produced concept maps and we think that of method described in [P1] can be used as an aid to create and edit pedagogically meaningfully individual concept maps. Also the method for finding the shortest paths between the learner's knowledge and the learning objective as introduced in publication [P6] can be seen as an expansion and corresponding idea to the method introduced in publication [P1].

PART III. Generation of alternative personalized learning paths in link based knowledge structures by using statistical and historical data

Chapter 6. Generating personalized learning paths from the Wikipedia by using article statistics

In publication [P3] we propose a new semi-automated method for generation of *personalized learning paths* by following hyperlink chains between articles of the Wikipedia online encyclopedia based on various *statistics of the articles*. The learning paths are represented with gradually built concept maps based on the hyperlink network of the Wikipedia online encyclopedia. On a more general level besides the Wikipedia, we propose methodology that supports exploiting knowledge structures in collaboratively maintained knowledge repositories in the form of wikis.

We now here first explain the basic idea and motivation about using statistical features of the Wikipedia articles to generate alternative learning paths and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational tasks. More details can be read from the original publication [P3]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P3]. Figure 6.1 illustrates the main idea of the method proposed in publication [P3].

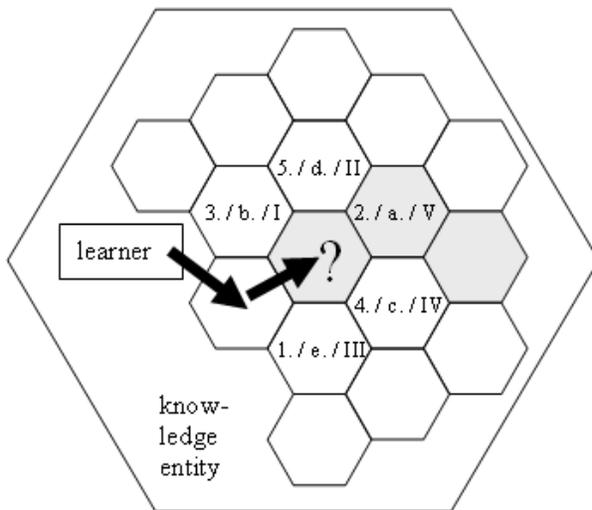


Figure 6.1. Main idea of the method proposed in publication [P3] for generating personalized learning paths by exploring in the hyperlink network of the Wikipedia based on ranking of article statistics.

Similarly as in Figure 5.1, also in Figure 6.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. We are extending the proposal of publication [P2] by enabling use of alternative strategies for a single learner traversing hyperlinks between articles. Now we use statistics about the Wikipedia articles to generate rankings for hyperlinks of an article in respect to alternative perspectives represented by target articles accessibly through these hyperlinks. In Figure 6.1 the alternative rankings in descending order of priority are represented by three parallel orderings based on Arabic numbers (1., 2., 3.,...), Latin alphabets (a., b., c.,...) and Roman numbers (I, II, III,...).

The learner's exploration path in the hyperlink network so far is shown by a chain of arrows. Surrounding the current article (a hexagon with a question mark) are articles reachable through hyperlinks of current article, each one of them supplied with three alternative ranking values in respect to three different statistical features of articles. When selecting what hyperlink to traverse next in further exploration, if the learner decides to prioritize ranking values shown in Latin alphabets, the highest-ranking hyperlink would lead her to article supplied with notation "2./a./V". In this example, grayed hexagons indicate a possible chain of hyperlinks that the learner is expected to traverse from current article.

6.1. Ontology construction and accumulating knowledge

Pirrone et al. (2005) proposed automated learning path generation inside a domain ontology relying on a weighted graph and A* (i.e. A star) search algorithm. In publication [P3] We suggested extending the use of ontologies extracted from the Wikipedia to be applied in building personalized learning paths. With an aim to enhance the quality of articles, the Wikipedia community has been labelling in a specific review process some satisfactory articles as "good articles" and even more professional ones as "featured articles". Blumenstock (Blumenstock 2008) showed that the featured articles can be recognized correctly with the accuracy of 96 percent using a simple heuristic that classifies articles with more than 2000 words as "featured" and articles with fewer than 2000 words as "random". Thomas and Sheth (Thomas & Sheth 2007) showed that when comparing labelled good articles to other non-stub articles having at least 50 revision milestones they found no statistically significant difference in convergence to a semantically stable state. These two previous results indicate that the maturity of an article can be measured relatively well even with simple parameters and motivated us to attempt to identify few *basic features of a Wikipedia article* that can be easily measured to create rankings for hyperlinks, highlighting alternative pedagogical perspectives that they provide for the learner's exploration in the hyperlink network.

When generating automatically favourable learning paths the learner should have a suitable balance between constraints for sustainability and freedom of association. Nastase and Szpakowicz (Nastase & Szpakowicz 2006) introduced an incremental learning algorithm that mimics how a human reader accumulates knowledge and exploits it to process new text. For natural language processing applications, various

confidence measures have been developed to estimate the probability of correctness of the outputs (Gandrabor et al. 2006). Pavlovic (Pavlovic 2008) proposed detecting semantic structures in a network based on available static data and ranking of paths. We think that our proposed method is dealing with a same kind of goal and that the statistics concerning articles can be useful criteria for ranking the paths. Haruechaiyasak and Damrongrat (Haruechaiyasak & Damrongrat 2008) proposed recommending related articles for the educationally tailored Wikipedia Selection for Schools based on similarity measures computed for topic distribution profiles of the articles.

There are some challenges with the learner's exploration in hyperlink network. The more hyperlinks are available at current article, the more *alternative learning paths* can be provided to the learner although making it also harder to choose one of them through comparison. Using many parallel measures for ranking hyperlinks can enhance possibility to systematically differentiate alternative rankings but unfortunately also increases computational complexity. We wanted to minimize the computational cost of searches in the hyperlink network and decided to evaluate only those articles that can be reached within a distance of one hyperlink step from the article where the learner's exploration currently stays. Thus our method can be used even with modest technological resources in accordance with promoting design principle of access for all. We think that there is a whole new research domain opening in this ranking-based exploration of wiki environments.

6.2. Ranking hyperlinks based on article statistics

We propose that many statistical features about the hyperlink's target article can be retrieved as useful indicators about the augmenting perspectives that the target article represents in relation to the current article. This enables getting target articles of hyperlinks to be promoted in varying order of preference, depending on to which statistical features have been given priority in ranking. In publication [P3] we concluded based on our analysis to name five key functions of the Wikipedia and corresponding measurable features for ranking of hyperlinks. They are: adding new content (*article size*), editing content (*editing rate*), providing cross-linking (*hierarchy of hyperlinks*), explaining concepts and their relation (*repetition of hyperlink terms*) and using articles as a reference (*viewing rate*). Each of these five features enable relatively straightforward ranking of hyperlinks of any Wikipedia article. We do not expect these five key functions necessarily to cover most fundamental ontological features of the Wikipedia but anyway to define a new useful approach to classify ranking alternatives in exploration of hyperlink network.

We think that the order of appearance of hyperlinks in the article is the simplest ranking of hyperlinks to exploit since it is inherently available in the article text. Statistical features of an article can be computed directly from the article or its *revision history*, or then retrieved from the open *statistics database* provided by the Wikipedia Foundation. Several specialized web sites provide an easy interface for making queries from the statistics database. In preliminary testing we evaluated a varied randomized

sample of 100 Wikipedia articles. Based on randomized sample of 100 Wikipedia articles we identified what kinds of target articles of hyperlinks appear to become logically or misleadingly favoured when ranking is performed in respect to each of five features (see Table 6.1 (originally published as Table 1 in publication [P3])).

Table 6.1. (originally published as Table 1 in publication [P3]). Some favourably and misleadingly promoted types of Wikipedia articles when their corresponding hyperlinks are ranked in respect to five measurable features.

	Hierarchy of hyperlinks	Repetition of hyperlink terms	Article size	Viewing rate	Editing rate
<i>Favourably promoted</i>	<ul style="list-style-type: none"> - compact definitions in the beginning - later illustrative and more detailed uses, alternatives 	<ul style="list-style-type: none"> - everyday vocabulary - general topic with many variations and sub-branches 	<ul style="list-style-type: none"> - key terms of each field - stabilized knowledge, biographies 	<ul style="list-style-type: none"> - recent news topics, trends in popular culture - technology, entertainment, celebrities 	<ul style="list-style-type: none"> - controversial, non-stabilized or actively evolving - science, politics
<i>Misleadingly promoted</i>	<ul style="list-style-type: none"> - any complex term that needs explanation - unnecessarily broad or general terms 	<ul style="list-style-type: none"> - use of synonyms or it/this hides the terms - long terms less likely to be repeated 	<ul style="list-style-type: none"> - single author's devotion without general interest - article not condensed or yet split 	<ul style="list-style-type: none"> - tourist information - checks for equations, minor facts or spelling 	<ul style="list-style-type: none"> - target of vandalism or consistent rewriting - translated article suffering from low rate

The learner's exploration in hyperlink network should fruitfully support principles of constructivism and transferable learning. Each selected hyperlink progressively expands a concept map that is shown to the learner, defining learning paths highlighting perspectives that depend on ranking alternative the learner has decided to prioritize. At each step, according to her personal needs, the learner can choose which type of ranking is used for sorting the hyperlinks. The hyperlinks are sorted based on five different rankings that are generated from the statistics of the hyperlinked articles in accordance with five key functions of the Wikipedia and respective measurable features as discussed above. In experiments described in publication [P3] we used following definitions for each of five key functions and in later supplementing experiments we have analyzed some additional measurable features as we will discuss a bit later in this Chapter 6.

“*Hierarchy of hyperlinks*” denotes showing hyperlinks in the natural order of increasing distance from the beginning of the article. This ordering is motivated by that a Wikipedia article often starts with a compact definition containing a few hyperlinks. Respectively, the hyperlinks in the end of current article likely point to articles whose titles emphasize giving broader details of the current article. “*Repetition of hyperlink terms*” denotes showing hyperlinks in a descending order of significance based on how many times the word (or group of words) forming the title of hyperlink's target article is mentioned in the current article, anywhere in its full textual content. This ordering is motivated by an assumption that the title of target article for each hyperlink defines a key term for current article. The more this key term is repeated in the text of current article, the more it seems to indicate that the corresponding target article is highly involved in formulating relations with the current article.

“*Article size*” denotes showing hyperlinks in a descending order based on the total amount of characters in the target article text. A motivation for this ordering is that a

bigger article size obviously indicates more detailed content than a smaller article size. The value of article size is approximated with the file size in bytes that is extracted from the header of the target article file. “*Viewing rate*” denotes showing hyperlinks in a descending order based on the frequency of visits to view the hyperlink’s target article by the global community. This ordering is motivated by the assumption that an article with a high viewing rate has a higher general interest than an article with a low viewing rate. This value represents the total number of views per previous full month. This information is retrieved from online service (Wikipedia article traffic statistics 2009) that relies on data gathered from Wikipedia’s squidbased cache server cluster.

“*Editing rate*” denotes showing hyperlinks in a descending order based on frequency of editing the hyperlink’s target article by the global community. A motivation for this ordering is that higher editing rates seem to indicate more verified content than lower editing rates. In publication [P3] the value of editing rate is approximated with the total number of edits for current article since its creation. However, in supplementing experiments which will be discussed later in this Chapter 6 we have carried out ranking of hyperlinks also based such definition of edit rate that is number of edits during a timespan divided by article size and we consider that this later definition usefully makes gained rate value more proportional than earlier definition. This information is retrieved from online service (Wikipedia page history statistics 2009) that builds an edit history overview page for the article with the given name. Besides these five principal features, we still suggest a supplementing feature that is a user-defined weighted mixture of them all.

There have been proposals to visually highlight the most mutually agreed segments in a Wikipedia article based on simple quality measures. High survival time of a single edit does not guarantee reliably its trustworthiness (Luyt et al. 2008). Adler and de Alfaro (Adler & de Alfaro 2007) proposed a measure relying on author’s reputation that can be gained if the edits he/she performs are preserved by subsequent authors. It seems challenging to develop measures taking simultaneously into account the semantics of the article network and collective contribution patterns coming from authors and readers. Our method tries to address these issues.

6.3. Building learning paths in hyperlink network of the Wikipedia

Initial empirical testing of the proposed method was carried out with a sample of 30 most frequent nouns in English retrieved from British National Corpus (based on a lemmatized word list Kilgarriff (Kilgarriff 1997), downloaded from (<http://www.kilgarriff.co.uk/BNClists/lemma.num>)). To illustrate the rich varied perspectives gained with our method Table 6.2 (originally published as Table 2 in publication [P3]) shows target articles of eight highest-ranking hyperlinks of Wikipedia article “Life” (as of October 2009). In each major column of the table hyperlinks are ranked separately based on each of the five measurable features discussed above. The columns “Main text” and “Only intro” indicate if the ranking is done for all hyperlinks

of the full article text (i.e. full text section) or only for hyperlinks mentioned in the introduction section before the table of contents (i.e. intro text section). Applying ranking only to those hyperlinks that are mentioned in introduction section seems to help highlighting fundamental relations and improves computational performance thus decreasing delay of getting results with the method.

Table 6.2. (originally published as Table 2 in publication [P3]). Ranking of hyperlinks of article "Life" in respect to five features.

Rank	Hierarchy of hyperlinks (ordinal number)		Repetition of hyperlink terms (times)		Article size (bytes)		Viewing rate (times per month)		Editing rate (total number of edits)	
	Main text	Only intro	Main text	Only intro	Main text	Only intro	Main text	Only intro	Main text	Only intro
1	Biota (ecology) 1	Biota (ecology) 1	Organism 59	Organism 59	Evolution 525544	Fungus 488952	Earth 372525	Earth 372525	Evolution 12233	Earth 9152
2	Object (philosophy) 2	Object (philosophy) 2	RNA 41	Gene 38	Fungi 489093	Metabolism 456427	Water 286508	Water 286508	Earth 9152	Philosophy 6905
3	Biological process 3	Biological process 3	Gene 38	Earth 33	Fungus 488952	Earth 417499	Evolution 206918	Religion 192527	Aristotle 7089	Death 6467
4	Death 4	Death 4	Earth 33	Biology 26	Metabolism 456427	Bacteria 407412	Religion 192527	Philosophy 180609	Philosophy 6905	Religion 5850
5	Biology 5	Biology 5	Evolution 32	Animal 25	Bird 440284	Archaea 354696	Aristotle 190096	Animal 173059	Death 6467	Water 5828
6	Organism 6	Organism 6	Biology 26	Plant 21	Earth 417499	Philosophy 220220	Virus 189972	Bacteria 153442	Religion 5850	Biology 5340

We can sum all types of rankings together for each hyperlink. Then three highest-ranking hyperlinks in descending order for the main text are Evolution, Earth and Organism, and for only the introduction section Earth, Philosophy and Organism. When ranking is done only for the hyperlinks mentioned in the introduction section (i.e. intro text section), the promoted hyperlinks appear to be more shared among various perspectives than when ranking is done for all hyperlinks of the full article text (i.e. full text section), and it can originate from a practice that introduction section of an article typically may offer a relatively diverse compact set of hyperlinks while the text of introduction section aims to position the article in broader context of other articles. When we evaluated characteristics emerging with each feature in Table 6.2 our findings matched well with our previously made hypothesis about distinctive characteristics for each feature used in ranking of hyperlinks (see Table 6.1).

We produced a set of *learning paths* in the form of concept maps by exploring hyperlink chains following the ranking in respect to five features described in Subchapter 6.2. We continued initial empirical testing with the previous sample of 30 English nouns. Figure 6.2 (originally published as Figure 1 in publication [P3]) shows concept maps that we produced for each of five perspectives when taking into account all hyperlinks in the full article text (i.e. full text section). Relation statements were extracted from sentences surrounding the hyperlinks with a method introduced in our previous work (publication [P2]). The method enables the learner to build concept maps with a free design in respect to branching, crosslinking and loops.

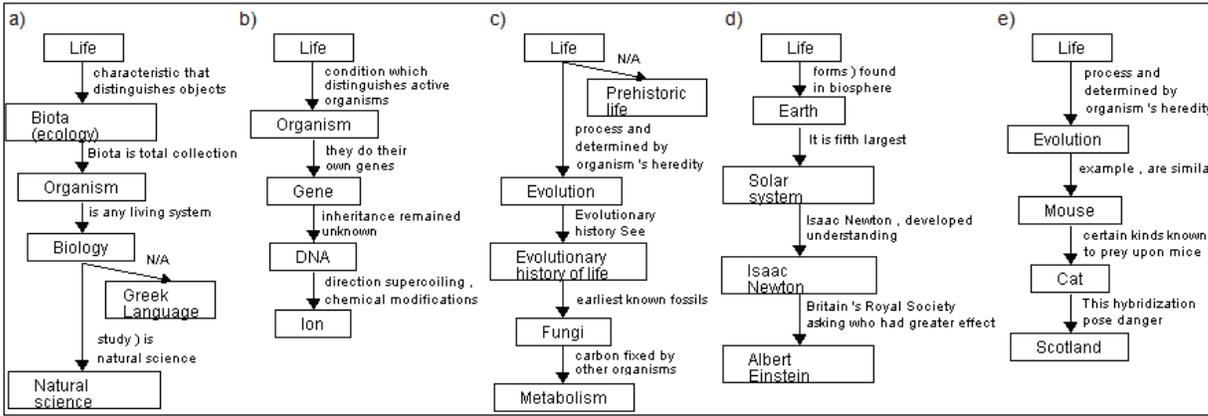


Figure 6.2. (originally published as Figure 1 in publication [P3]). Learning paths starting from article "Life" with five alternative perspectives: a) hierarchy of hyperlinks, b) repetition of hyperlink terms, c) article size, d) viewing rate, and e) editing rate.

Evaluating the learning paths introduced by each of the five features gave promising results. The learning paths seemed to offer some distinctive perspectives corresponding to our previous hypothesis that we outlined in Table 6.1. Hierarchy of hyperlinks (Figure 6.2a) produced a learning path that remains constantly on relatively high level of conceptual hierarchy in the topic. This type of learning paths could effectively introduce for example main chapters of the curriculum. Repetition of hyperlink terms (Figure 6.2b) produced a path that goes through conceptual structures of the topic across various hierarchical levels. This type of path could suit well to learning how the curriculum in deeper levels relies on rich variations of some basic conceptual components. Article size (Figure 6.2c) produced a path highlighting a collection of the most broadly documented concepts of the topic. This type of path could help in getting idea about the most respected and stabilized parts of the curriculum. Viewing rate (Figure 6.2d) produced a path showing those concepts of the topic that get the most attention from the general public. This type of path could indicate which parts of the curriculum are the most referenced ones. Editing rate (Figure 6.2e) produced a path that offers concepts in the topic that are actively debated by the general public. This type of path could illustrate the parts of curriculum that are involved in constructive criticism and reconsideration.

While ranking the hyperlinks, major articles can easily dominate all rankings and we suggest creating more distinctive diversity to different rankings by normalizing comparable statistics of articles somehow. We identified that a promising way to identify *proportional values* instead of absolute values can be based on idea of information density, i.e. statistical value per one unit of information. Thus, in practice for example hierarchy of hyperlinks, repetition of hyperlink terms, viewing rate and editing rate could be considered proportionally, for example in relation to article size.

Table 6.3 shows for 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks for departing and arriving hyperlinks (full listing is shown in Appendix U). Table 6.4 shows the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms for departing and arriving hyperlinks (full listing is shown in Appendix V).

We decided to make some further analysis about the behavior of statistical features of Wikipedia articles and its effect on chaining concepts in a way that could be pedagogically beneficial, and we identified that indeed especially the feature we have earlier referred to as “editing rate” seems to have correlations with “article size”. To suggest a compact and simple yet expressive collection of statistical features that offer alternative emphasis we thus decided to replace in our further analysis the feature “editing rate” with a feature “*edit rate per article size*” which seemed to offer promising results.

There can be many fruitful alternative ways to define statistical features by using varying time ranges. Table 6.5 enables to compare for Wikipedia articles corresponding to 102 core concepts following statistical features that offer one possible approach relying on one selected time range: article size (file size in bytes) in end of February 2008, viewing rate in February 2008 (number of views during February 2008), editing rate (number of edits during year 2007) and editing rate per article size (number of edits during year 2007 divided by article size in end of February 2008). When considering 55 concepts belonging to “hyperlink network of 55 concepts” it can be seen from Table 6.5 that three highest-ranking concepts for each four rankings based statistical features show varying topical emphasis and are in decreasing order of ranking: Cat, Oxygen and Sun (ranking based on article size); Love, Dog and Cat (ranking based on viewing rate); Television, Cat and War (ranking based on editing rate); and Mother, Home and Child (ranking based on editing rate per article size).

Based on Table 6.5 for each of five comparison tests Table 6.6 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between four rankings of 102 core concepts in respect to following statistical features of Wikipedia articles: article size (file size), views, edits and edits per article size.

Table 6.3 part 1 of 2 (starts here and continues on next page). For 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks for departing and arriving hyperlinks (full listing shown in Appendix U). If observed concept has only one departing/arriving hyperlink then observed concept is supplied with an asterisk (*). Value of “position among hyperlinks departing from Wikipedia article of start concept” indicates for the highest-ranking start concept or end concept what is its ranking position among all start concepts (in natural order of increasing distance from the beginning of the article) of those hyperlinks that arrive to current end concept (N/A = not available).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (position among hyperlinks departing from Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (position among hyperlinks departing from Wikipedia article of start concept)
Adolescence	Childhood (1)		Adolescence	Childhood (1)
Animal	Organism (1)		Animal	Plant (2)
Atmosphere_of_Earth	Oxygen (1)		Atmosphere_of_Earth	Nature (5)
* Automobile	Oxygen (1)		Automobile	Oxygen (1)
Bed	Infant (1)		* Bed	Dream (3)
Biology	Evolution (1)		Biology	Evolution (1)
Birth	Animal (1)		* Birth	Parent (N/A)
Book	Paper (1)		Book	Paper (1)
Bread	Water (1)		* Bread	Food (4)
Cat	Human (1)		Cat	Dog (2)
Child	Parent (1)		Child	Parent (1)
Childhood	Child (1)		Childhood	Child (1)
City	Automobile (1)		* City	Human (N/A)
Clock	Time (1)		Clock	Time (1)
Clothing	Religion (1)		Clothing	Paper (4)
Computer	Television (1)		Computer	Clock (N/A); Food (N/A)
Death	Organism (1)		Death	Disease (2)
Diet_(nutrition)	Organism (1)		Diet_(nutrition)	Health (2)
* Disease	Death (1)		Disease	Death (1)
Dog	Pet (1)		Dog	Pet (1)
Dream	God (1)		* Dream	Bed (2)
Eating	Food (1)		Eating	Food (1)
Education	Learning (1)		Education	Learning (1)
Emotion	Experience (1)		Emotion	Sadness (3)
Evolution	Biology (1)		Evolution	Biology (1)
Experience	Time (1)		Experience	Emotion (N/A); Learning (N/A); World (N/A)
Family	Marriage (1)		Family	Marriage (1)
Father	Parent (1)		Father	Parent (1)
Flower	Evolution (1)		Flower	Plant (2)
Food	Eating (1)		Food	Eating (1)
Forest	Tree (1)		Forest	Tree (1)
Friendship	Philosophy (1)		* Friendship	Love (3)
Future	Time (1)		Future	Time (1)
* Goal	Purpose (1)		Goal	Purpose (1)
God	Religion (1)		God	Religion (1)
* Ground	Philosophy (1)		Happiness	Emotion (1)
Happiness	Emotion (1)		Hatred	Emotion (1)
Hatred	Emotion (1)		Health	Physical_fitness (2)
Health	Disease (1)		Heart	Oxygen (N/A); Death (N/A); Organism (N/A)
Hobby	Leisure (1)		* Home	House (2)
Home	Family (1)		Hospital	Bed (N/A); Infant (N/A)
Hospital	Disease (1)		House	Home (2)
House	Family (1)		Human	Animal (9)
Human	City (1)		Infant	Child (1)
Infant	Child (1)		Joy	Happiness (1)
* Joy	Happiness (1)		Learning	Education (2)
Learning	Experience (1)		Leisure	Education (4)
Leisure	Time (1)		Light	Time (1)
Light	Time (1)		Love	Emotion (2)
Love	Family (1)		Marriage	Family (2)
Marriage	Religion (1)		* Money	Bread (N/A)

Table 6.3 part 2 of 2 (started on previous page and continues here).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (position among hyperlinks departing from Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (position among hyperlinks departing from Wikipedia article of start concept)
Money	Water (1)		Mother	Parent (1)
Mother	Parent (1)		Music	Human (N/A); Book (N/A); Pleasure (N/A); Party (N/A); Philosophy (N/A); Test (assessment) (N/A)
Music	Religion (1)		Nature	Plant (5)
Nature	Human (1)		Old age	Infant (3)
Old age	Biology (1)		Organism	Biology (1)
Organism	Biology (1)		Oxygen	Plant (1)
Oxygen	Plant (1)		Paper	Book (1)
Paper	Book (1)		Parent	Father (1)
Parent	Father (1)		* Peace	War (2)
Party	Music (1)		* People	Pet (N/A)
Peace	Education (1)		Pet	Dog (2)
* Pen	Paper (1)		Philosophy	Religion (1)
People	Human (1)		Physical fitness	Health (1)
Pet	Animal (1)		Plant	Organism (1)
Philosophy	Religion (1)		Pleasure	Emotion (1)
Physical fitness	Health (1)		Purpose	Goal (1)
Plant	Organism (1)		Rain	Water (1)
Pleasure	Emotion (1)		Religion	Philosophy (1)
Purpose	Goal (1)		Sadness	Emotion (1)
Rain	Water (1)		School	Teacher (1)
Religion	Philosophy (1)		* Sea	Water (1)
Sadness	Emotion (1)		Sibling	Parent (1)
School	Teacher (1)		* Sorrow	Sadness (1)
* Sea	Water (1)		Sport	Adolescence (N/A); Hobby (N/A); Oxygen (N/A)
* Shoe	Clothing (1)		Sun	Oxygen (1)
Sibling	Parent (1)		Teacher	Education (1)
* Sorrow	Sadness (1)		* Telephone	Computer (N/A)
* Sport	Television (1)		Television	Time (N/A); Music (N/A); Adolescence (N/A); Clothing (N/A); Computer (N/A); House (N/A); Leisure (N/A); Light (N/A); Party (N/A); Sport (N/A)
* Summer	Plant (1)		Time	Clock (3)
Sun	Oxygen (1)		* Travel	Water (N/A)
Teacher	Education (1)		Tree	Forest (2)
Test (assessment)	Education (1)		War	Peace (4)
Time	Religion (1)		Water	Sea (1)
Tree	Oxygen (1)		* Work	Leisure (N/A)
War	Hatred (1)			
Water	Sea (1)			
World	Human (1)			

Table 6.4 part 1 of 2 (starts here and continues on next page). For 102 core concepts the highest-ranking end concepts and start concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms for departing and arriving hyperlinks (full listing shown in Appendix V). If observed concept has only one departing/arriving hyperlink then observed concept is supplied with an asterisk (*).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)	Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)
Adolescence	Child (14)	Adolescence	Child (14)
Animal	Plant (10)	Animal	Plant (10)
Atmosphere of Earth	Oxygen (17)	Atmosphere of Earth	Plant (4)
* Automobile	Oxygen (2)	Automobile	City (4)
Bed	Hospital (4)	* Bed	Dream (0)
Biology	Organism (57)	Biology	Organism (57)
Birth	Mother (5)	* Birth	Parent (1)
Book	Paper (31)	Book	Paper (31)
Bread	Water (20)	* Bread	Food (17)
Cat	Human (62)	Cat	Pet (22)
Child	Childhood (3)	Child	Childhood (3)
Childhood	Child (26)	Childhood	Child (26)
City	Automobile (2)	* City	Human (1)
Clock	Time (79)	Clock	Time (79)
Clothing	Paper (2); Religion (2)	Clothing	Human (10)
Computer	Telephone (1); Television (1)	Computer	Clock(0); Food(0)
Death	Disease (14)	Death	Disease (14)
Diet (nutrition)	Health (4)	Diet (nutrition)	Food (17)
* Disease	Death (1)	Disease	Health (8)
Dog	Pet (19)	Dog	Pet (19)
Dream	Bed(1); God(1)	* Dream	Bed (1)
Eating	Food (14)	Eating	Food (14)
Education	Learning (48)	Education	Learning (48)
Emotion	Experience (12)	Emotion	Human (15)
Evolution	Organism (75)	Evolution	Organism (75)
Experience	Philosophy (2)	Experience	Emotion (1)
Family	Child (51)	Family	Child (51)
Father	Family (12)	Father	Family (12)
Flower	Plant (63)	Flower	Plant (63)
Food	Animal (30)	Food	Health (19)
Forest	Tree (33)	Forest	Tree (33)
Friendship	Love (14)	* Friendship	Love (14)
Future	Time (10)	Future	Time (10)
* Goal	Purpose (1)	Goal	Purpose (1)
God	Religion (20)	God	Religion (20)
* Ground	Philosophy (1)	Happiness	Emotion (8)
Happiness	Emotion (8)	Hatred	Emotion(0); Love(0); Pleasure(0); Sadness(0); War(0)
Hatred	Emotion(0); Happiness(0)	Health	Physical_fitness (10)
Health	Disease (15)	Heart	Oxygen (2)
Hobby	Sport (6)	* Home	House (1)
Home	Family(1); House(1); Love(1)	Hospital	Bed (3)
Hospital	Health (15)	House	Home (12)
House	Home (12)	Human	World (54)
Human	Evolution (72)	Infant	Child (18)
Infant	Child (18)	Joy	Emotion(1); Happiness(1)
* Joy	Happiness (1)	Learning	Education (5)
Learning	Time (6)	Leisure	Education (3)
Leisure	Time (22)	Light	Time (11)
Light	Time (11)	Love	Human (13)
Love	Friendship (8)	Marriage	Family (38)
Marriage	Family (38)	* Money	Bread (0)

Table 6.4 part 2 of 2 (started on previous page and continues here).

Observed concept	Highest-ranking <u>end</u> concept for hyperlink departing from observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)		Observed concept	Highest-ranking <u>start</u> concept for hyperlink arriving to observed concept (repetitions of hyperlink terms in Wikipedia article of start concept)
Money	Water (2)		Mother	Father (3)
Mother	Father (3)		Music	Human (7)
Music	Time (10)		Nature	Plant (31)
Nature	Human (39)		Old_age	Human (2)
Old_age	Biology(1); Child(1)		Organism	Animal (15)
Organism	Plant (12)		Oxygen	Water (41)
Oxygen	Water (41)		Paper	Book (9)
Paper	Book (9)		Parent	Mother (24)
Parent	Mother (24)		* Peace	War (8)
Party	Music (7)		* People	Pet (0)
Peace	War (8)		Pet	Cat (20)
* Pen	Paper (3)		Philosophy	Human (23)
People	Human (5)		Physical_fitness	Health (3)
Pet	Animal (40)		Plant	Food (13)
Philosophy	Religion (7)		Pleasure	Love (2)
Physical_fitness	Health (3)		Purpose	Goal(5); People(5)
Plant	Tree (16)		Rain	Water (14)
Pleasure	Philosophy (3)		Religion	God (18)
Purpose	Happiness(8); Philosophy(8)		Sadness	Emotion (3)
Rain	Water (14)		School	Education (23)
Religion	God (18)		* Sea	Water (9)
Sadness	Emotion (3)		Sibling	Child (32)
School	Education (23)		* Sorrow	Sadness (1)
* Sea	Water (9)		Sport	Adolescence(0); Hobby(0); Oxygen(0)
* Shoe	Clothing (1)		Sun	Light (24)
Sibling	Parent (16)		Teacher	School (22)
* Sorrow	Sadness (1)		* Telephone	Computer (2)
* Sport	Television (4)		Television	Time (6)
* Summer	Plant (1)		Time	Clock (24)
Sun	Oxygen (3)		* Travel	Water (0)
Teacher	School (22)		Tree	Plant (14)
Test_(assessment)	Education (5)		War	Human (23)
Time	Philosophy (26)		Water	Food (26)
Tree	Forest (5)		* Work	Leisure (0)
War	Peace (21)			
Water	Human (27)			
World	Human (5)			

To facilitate identifying possible similarities between frequency distributions of Table 6.5 we transformed for representation of Table 6.6 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of article size for each of 102 core concepts has a weighting parameter 1; scaled frequency distribution of views for each of 102 core concepts has a weighting parameter 0.34; scaled frequency distribution of edits for each of 102 core concepts has a weighting parameter 32.5; and scaled frequency distribution of edits per article size for each of 102 core concepts has a weighting parameter 470000. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 6.5 part 1 of 2 (starts here and continues on next page). Comparison of 102 core concepts based on Wikipedia article statistics: article size (file size in bytes) in end of February 2008, viewing rate in February 2008 (number of views during February 2008), editing rate (number of edits during year 2007) and editing rate per article size (number of edits during year 2007 divided by article size in end of February 2008).

Article size (file size) in end of February 2008 in bytes		Number of views during February 2008		Number of edits during year 2007		Number of edits during year 2007 divided by article size in end of February 2008	
<i>Concept</i>	<i>Bytes</i>	<i>Concept</i>	<i>Views</i>	<i>Concept</i>	<i>Edits</i>	<i>Concept</i>	<i>Edits per article size</i>
Evolution	118194	Love	560808	Evolution	2972	Fun	0.458333333
Cat	88984	Dog	308653	Television	2459	People	0.234086242
Oxygen	78434	Cat	296740	Money	2304	Mother	0.194289261
Sun	77766	Book	268020	Cat	2183	Home	0.167356798
Human	75739	Water	257835	War	2021	Child	0.165239393
Dog	75145	Sun	223969	Music	1935	World	0.159197223
War	69606	Computer	209842	Sun	1905	Television	0.134717581
Time	68785	Evolution	195237	Oxygen	1894	Old_age	0.109980361
Philosophy	66774	Heart	184184	Animal	1871	Pen	0.108827711
Water	63420	Music	183726	Water	1734	Physical_fitness	0.107252014
Marriage	62034	Human	180621	Marriage	1706	Heart	0.107237339
Nature	60605	Animal	179568	Philosophy	1619	Happiness	0.0971965
Computer	58057	Religion	167871	Automobile	1578	Summer	0.083108957
Religion	50637	Television	156359	Book	1566	Money	0.082737817
Music	50062	God	134822	Happiness	1522	Teacher	0.075267464
City	44698	House	132610	Dog	1428	Work	0.074921956
Plant	43161	Philosophy	132590	God	1400	Purpose	0.068502825
Book	40981	Oxygen	128650	Biology	1399	House	0.06661375
Education	37721	Death	121652	People	1368	Animal	0.063436631
Food	37680	Flower	121637	Plant	1332	Environment	0.062946429
Automobile	37300	Plant	118399	Tree	1297	Travel	0.059021922
Bread	37123	Tree	106225	Atmosphere_of_earth	1253	Telephone	0.057976401
Clock	36208	War	105792	Mother	1252	Peace	0.055853211
Biology	35869	Marriage	104131	Telephone	1248	Atmosphere_of_earth	0.053464755
Tree	35572	Automobile	101972	Teacher	1196	Infant	0.053329782
Death	34343	Dream	97321	Time	1196	Shoe	0.051473867
Love	34335	Biology	97177	Dream	1141	Rain	0.050762723
Emotion	33427	Education	96896	Heart	1135	Party	0.048622493
Flower	33338	Management	95452	Death	1109	Eating	0.047850613
Organism	33213	Food	92214	House	1091	Holiday	0.045847176
God	31357	Time	92193	Food	1055	Sport	0.04490985
Light	31244	Light	86018	World	1055	God	0.044647128
Animal	29494	Sport	85181	Shoe	1039	Dream	0.04421281
Money	27847	Telephone	82093	Human	1030	Disease	0.043114583
Hospital	27751	Money	79803	Paper	1009	Automobile	0.04230563
Dream	25807	Emotion	79026	Infant	1001	Health	0.04191376
Family	25451	Disease	72739	Computer	984	Paper	0.041563684
Forest	24923	Family	72685	Light	976	Friendship	0.040647906
Adolescence	24293	Health	65829	Education	975	Birth	0.040327411
Paper	24276	Friendship	59526	Flower	910	Study	0.040277778
Atmosphere_of_Earth	23436	Clothing	59331	Adolescence	865	Biology	0.039003039
Management	23018	Bread	58119	Religion	851	Music	0.038652071
Telephone	21526	Paper	57408	Child	849	Book	0.03821283
Shoe	20185	Adolescence	57314	Love	843	Goodness	0.037037037
Health	19898	Bed	55373	Pen	842	Sea	0.036694826
Chair	19747	City	53793	Health	834	Tree	0.036461262
Clothing	19718	Forest	50638	Sport	817	Diet_(nutrition)	0.035967818
Friendship	19509	Peace	50351	Bread	803	Adolescence	0.035606965
Infant	18770	School	50336	Friendship	793	Death	0.032291879
Television	18253	Happiness	48919	Rain	792	Light	0.031237998
Test_(assessment)	18196	Rain	48337	Peace	761	Plant	0.030861194
Sport	18192	Summer	48255	Clock	750	Clothing	0.03073334
School	16519	World	43439	Disease	701	Bed	0.03038674
House	16378	Home	41882	Party	623	Pet	0.030365087
Disease	16259	Organism	41369	Old_age	616	Pleasure	0.029228687
Teacher	15890	Clock	39217	Clothing	606	War	0.029034853

Table 6.5 part 2 of 2 (started on previous page and continues here).

Article size (file size) in end of February 2008 in bytes		Number of views during February 2008		Number of edits during year 2007		Number of edits during year 2007 divided by article size in end of February 2008	
<i>Concept</i>	<i>Bytes</i>	<i>Concept</i>	<i>Views</i>	<i>Concept</i>	<i>Edits</i>	<i>Concept</i>	<i>Edits per article size</i>
Happiness	15659	Work	38983	Emotion	605	Food	0.027998938
Rain	15602	Holiday	37573	Holiday	552	Father	0.027906598
Learning	14536	Teacher	35626	City	523	Marriage	0.027501048
Pet	14161	Sea	34652	Chair	493	Water	0.027341533
Bed	13756	Nature	34207	Home	485	Flower	0.027296179
Peace	13625	Environment	33546	Management	473	Future	0.027117385
Sibling	13610	Physical_fitness	31456	Summer	463	Education	0.025847671
Hobby	13582	Pet	30802	Family	462	Evolution	0.0251451
Party	12813	Hospital	28086	Organism	442	Chair	0.024965818
Father	12291	People	27257	Forest	433	Joy	0.024900036
Holiday	12040	Learning	27194	Pet	430	Love	0.024552206
Heart	10584	Sibling	25728	Bed	418	Cat	0.0245325
Leisure	9685	Child	24547	Nature	391	Sun	0.024496567
Goal	9516	Infant	23134	Physical_fitness	386	Philosophy	0.024245964
Parent	8574	Mother	22343	Hospital	351	Oxygen	0.024147691
Future	8076	Travel	21983	Father	343	Growing	0.022160665
Pen	7737	Birth	21011	School	326	Bread	0.021630795
Sea	7576	Shoe	19289	Learning	282	Clock	0.020713654
World	6627	Future	18688	Sea	278	Management	0.020549135
Sadness	6549	Leisure	18122	Eating	246	School	0.019734851
Mother	6444	Pen	17530	Diet_(nutrition)	228	Learning	0.01940011
Diet_(nutrition)	6339	Party	17262	Future	219	Parent	0.019127595
Childhood	6153	Chair	17035	Birth	202	Dog	0.01900326
People	5844	Diet_(nutrition)	16889	Sibling	179	Hatred	0.018597997
Old_age	5601	Old_age	16508	Parent	164	Family	0.018152528
Summer	5571	Pleasure	15901	Leisure	149	Emotion	0.018099141
Joy	5502	Hobby	15692	Hobby	144	Time	0.017387512
Eating	5141	Sadness	15214	Work	144	Forest	0.01737351
Child	5138	Childhood	14511	Environment	141	Computer	0.016948861
Birth	5009	Hatred	13967	Joy	137	Religion	0.016805893
Experience	4430	Father	12520	Test_(assessment)	113	Childhood	0.015439623
Pleasure	3695	Purpose	11672	Pleasure	108	Leisure	0.015384615
Physical_fitness	3599	Experience	11418	Travel	105	Sorrow	0.015151515
Hatred	3495	Goal	9252	Purpose	97	Experience	0.013769752
Home	2898	Eating	7412	Childhood	95	Human	0.013599335
Environment	2240	Joy	7303	Sadness	74	Organism	0.013308042
Work	1922	Fun	6767	Hatred	65	Sibling	0.013152094
Travel	1779	Parent	6580	Experience	61	Hospital	0.012648193
Ground	1467	Ground	4298	Study	29	Living	0.012608353
Purpose	1416	Study	4241	Living	16	City	0.011700747
Living	1269	Sorrow	3780	Goal	15	Sadness	0.011299435
Sorrow	792	Living	3118	Ground	12	Hobby	0.010602268
Study	720	Growing	2594	Sorrow	12	Ground	0.008179959
Growing	361	Goodness	1581	Fun	11	Nature	0.006451613
Goodness	27	Atmosphere_of_Earth	142	Growing	8	Test_(assessment)	0.006210156
Fun	24	Test_(assessment)	0	Goodness	1	Goal	0.001576293

Table 6.6. Degrees of dependency between four rankings of 102 core concepts in respect to following statistical features of Wikipedia articles: article size, views, edits and edits per article size.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
article size for each of 102 core concepts (scaled)	views for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.8221 (null hypothesis Hks not rejected)	gamma=0.609008 (standard error 0.1116137); null hypothesis Hgk rejected (p=4.859052×10 ⁻⁸)	rho= 0.7962692; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.609008; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
article size for each of 102 core concepts (scaled)	edits for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.2919 (null hypothesis Hks not rejected)	gamma=0.5698465 (standard error 0.1156813); null hypothesis Hgk rejected (p=8.392919×10 ⁻⁷)	rho= 0.7487518; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau= 0.5696252; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
article size for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.1625 (null hypothesis Hks not rejected)	gamma=-0.2118035 (standard error 0.1375269); null hypothesis Hgk not rejected (p=0.1235389)	rho= -0.2904083; null hypothesis Hsr rejected (p=0.003172)	tau= -0.2118035; null hypothesis Hkr rejected (p=0.001608)
views for each of 102 core concepts (scaled)	edits for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.22 (null hypothesis Hks not rejected)	gamma=0.6258014 (standard error 0.1098014); null hypothesis Hgk rejected (p=1.202335×10 ⁻⁸)	rho= 0.7961368; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau= 0.6255584; null hypothesis Hkr rejected (p<2.2×10 ⁻¹⁶)
views for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.08346 (null hypothesis Hks not rejected)	gamma=0.0277616 (standard error 0.1406653); null hypothesis Hgk not rejected (p=0.8435464)	rho= 0.05822415; null hypothesis Hsr not rejected (p=0.5605)	tau= 0.0277616; null hypothesis Hkr not rejected (p=0.6793)
edits for each of 102 core concepts (scaled)	edits per article size for each of 102 core concepts (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.001574 (null hypothesis Hks rejected)	gamma=0.2189625 (standard error 0.1373581); null hypothesis Hgk not rejected (p=0.1109136)	rho= 0.3199792; null hypothesis Hsr rejected (p=0.001044)	tau= 0.2188775; null hypothesis Hkr rejected (p=0.00112)

Based on Table 6.3 and Table 6.4 as well as Appendix J and Table 6.5 we have generated Figure 6.3 that shows *alternative conceptual link structures* formed with 55 concepts belonging to “hyperlink network of 55 concepts” when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including *hierarchy of hyperlinks*, *repetition of hyperlink terms*, *article size*, *viewing rate* and *editing rate per article size*. For each five alternative statistical features considered in subfigures a, b, c, d and e we have supplied each concept primarily with two hyperlinks: *highest-ranking departing hyperlink* and *highest-ranking arriving hyperlink*.

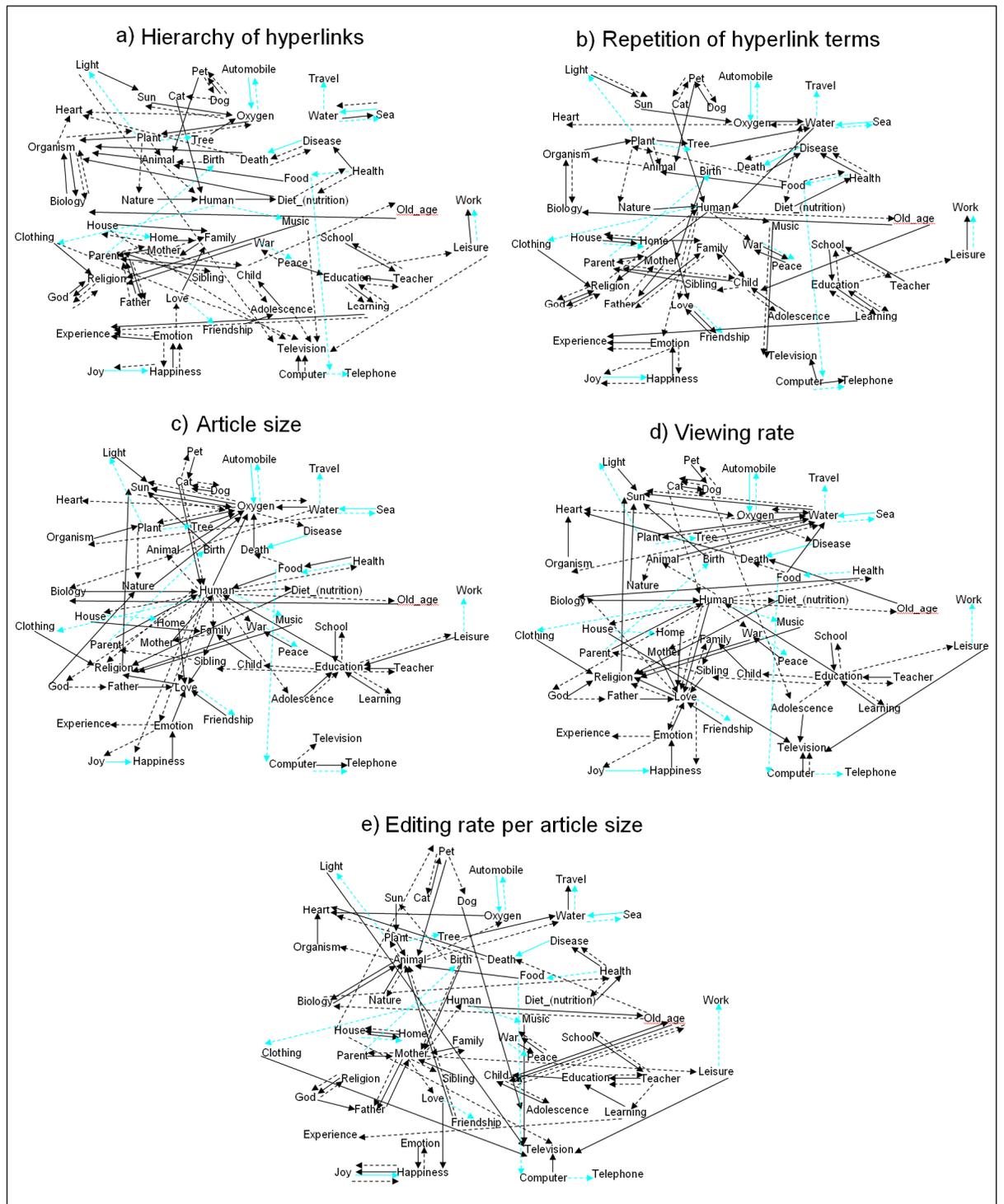


Figure 6.3. Conceptual link structures formed with 55 concepts belonging to “hyperlink network of 55 concepts” when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks (a), repetition of hyperlink terms (b), article size (c), viewing rate (d) and edits per article size (e). Each concept is primarily supplied with two hyperlinks: highest-ranking departing hyperlink indicated with solid line and highest-ranking arriving hyperlink indicated with dotted line. If several links share the position as the highest-ranking link they all are included in the figure as parallel links (for example in subfigure a) both links Emotion → Experience and Learning → Experience arrive at concept Experience). Turquoise lines indicate links that are the sole connecting arriving/departing link for current start/end concept of hyperlink and thus link becomes selected to be also the highest-ranking link (i.e. no alternative connecting links were available when selecting highest-ranking link).

In Figure 6.3 it needs to be noted that the five rankings with two opposite linking directions do not have equal properties and thus comparison of characteristics of conceptual link structures formed based on these ten different approaches can be a bit challenging. Hierarchy of hyperlinks and repetition of hyperlink terms measure statistical features that are present in the start concept of a hyperlink (i.e. on departing side of the hyperlink) whereas article size, viewing rate and editing rate per article size (as well as editing rate itself) measure statistical features that are present in the end concept of a hyperlink (i.e. on arriving side of the hyperlink). Since each concept is primarily supplied with a highest-ranking departing hyperlink and a highest-ranking arriving hyperlink it means that for example in respect to statistical feature “article size” the departing hyperlink of current concept is based on sizes of those articles that are linked to from current concept and the arriving hyperlink of current concept is based on sizes of those articles that link to current concept.

We wanted to better see which concepts in “hyperlink network of 55 concepts” have high level of occurrences as end concepts of arriving hyperlinks or start concepts of departing hyperlinks when concepts are chained based on five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size. To address this we have generated two tables, Table 6.7 shows *most frequently occurring end concepts in highest-ranking departing hyperlinks* in “hyperlink network of 55 concepts” and Table 6.8 shows *most frequently occurring start concepts in highest-ranking arriving hyperlinks* in “hyperlink network of 55 concepts”. It appears that each of five alternative statistical features emphasize concepts somewhat differently thus opening possibilities to gain alternative perspectives to connectivity of concepts in network.

Similarly as in Chapter 5 concerning most actively traversed hyperlinks, we think that various forms of interactive and engaging learning activities can be developed based student’s exploration in hyperlink network along exploration paths that proceed in “hyperlink network of 55 concepts” those arriving or departing hyperlinks that have the highest ranking in respect to each of five alternative statistical features of corresponding Wikipedia articles, including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size.

To show some examples we generated a set of ten *learning paths* based on exploration paths in “hyperlink network of 55 concepts” starting from concept Human and *proceeding to highest-ranking end concepts of departing hyperlinks* or *highest-ranking start concepts of arriving hyperlinks* in respect to five alternative statistical features (hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size). Thus based on hyperlinks shown in Figure 6.3 we generated ten learning paths shown in Table 6.9.

Table 6.7. Most frequently occurring end concepts in highest-ranking departing hyperlinks in “hyperlink network of 55 concepts”.

Hierarchy of hyperlinks		Repetition of hyperlink terms		Article size		Viewing rate		Editing rate per article size	
<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>
Organism	5	Human	4	Oxygen	9	Love	7	Animal	6
Parent	4	Child	3	Human	6	Religion	6	Mother	5
Religion	4	Family	3	Education	5	Water	6	Television	5
Animal	3	Religion	3	Love	5	Sun	5	Child	3
Family	3	Water	3	Religion	5	Television	4	Happiness	3
Oxygen	3	Animal	2	Sun	4	Education	3	Heart	3
Biology	2	Disease	2	Cat	2	Human	3	Education	2
Education	2	Education	2	Family	2	Death	2	Father	2
Experience	2	Experience	2			Dog	2	Old_age	2
Human	2	Mother	2			Heart	2	Water	2
		Oxygen	2			Oxygen	2		
		Plant	2						
		Television	2						

Table 6.8. Most frequently occurring start concepts in highest-ranking arriving hyperlinks in “hyperlink network of 55 concepts”.

Hierarchy of hyperlinks		Repetition of hyperlink terms		Article size		Viewing rate		Editing rate per article size	
<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>
Family	3	Human	9	Human	15	Human	10	Mother	7
Human	3	Education	4	Education	6	Education	6	Animal	5
Pet	3	Cat	3	Oxygen	6	Love	6	Health	3
Plant	3	Family	3	Water	4	Water	6	House	3
Biology	2	Oxygen	3	Cat	3	Dog	3	Old_age	3
Cat	2	Parent	3	Plant	3	Oxygen	3	Teacher	3
Child	2	Plant	3	Computer	2	Animal	2	Birth	2
Computer	2	Water	3	Emotion	2	Cat	2	Child	2
Diet_(nutrition)	2	Emotion	2	Food	2	Computer	2	Happiness	2
Dog	2	Food	2			Emotion	2	Human	2
Emotion	2	Health	2			Food	2	Pet	2
Food	2	House	2			Plant	2	Plant	2
Friendship	2	Light	2					Water	2
God	2	Pet	2						
Happiness	2	Sibling	2						
Health	2								
Home	2								
House	2								
Love	2								
Organism	2								
Oxygen	2								
Parent	2								
Peace	2								
Sibling	2								
Teacher	2								
War	2								
Water	2								

When chaining relation statements of hyperlinks (shown Appendix J) for the learning path for hierarchy of hyperlinks along departing hyperlinks (shown in Table 6.9) we gain a following *educational story* (start concept of hyperlink indicated with italics and end concept of hyperlink with underlining):

Concerning *humans* body size is significantly influenced by environmental factors such as diet.

The *diet* is the sum of food consumed by an organism.

In biology an *organism* is an individual living system.

Based on *biology* all organisms descend from a common ancestor or gene pool.

We think that these ten different types of exploration paths (illustrated with examples in Table 6.9) can provide useful alternative perspectives for adoption of knowledge and acquiring conceptualization about learning topic. Learning paths generated based on exploration paths in respect to different statistical features can highlight different conceptual relationships and structures thus addressing different needs of learning.

As discussed in Chapter 5 concerning most actively traversed hyperlinks, we think that also exploration in respect to different statistical features can offer interesting insight to the student's conceptualization and personal characteristics as well as to the semantical properties of language and consciousness. And also those concepts that belong to repeating cycle that define limits to expansion of exploration path may indicate when generated based on different statistical features some essential properties about semantics and how conceptualization inherently emerges in human mind.

Please note that in our previous analysis discussed in Subchapter 5.3 we encountered similar feature of arriving to a repeating cycle, and we already suggested that this process of arriving to a repeating cycle that we have identified in the Wikipedia (which holds small-world properties (Ingawale et al. 2009)) is related to previous findings of Kinouchi et al. (2002) that a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step). It can be possible to purposefully avoid entering an eternal cycle in exploration so that when arriving again to a previously visited concept now the learner chooses different ranking method than used previously. So if the learner previously proceeded hyperlinks in hyperlink network in respect to repetition of hyperlink terms he can now instead continue proceeding hyperlinks in respect to article size and thus a new branching emerges to traversed path enabling continuing exploration along yet unexplored hyperlinks.

When comparing ten learning paths generated based on statistical features (shown in Table 6.9) with learning path generated based on relationships of concept maps and learning path generated based on "hyperlink network of 55 concepts" (shown in Chapter 5) it seems that learning paths based on statistical features offer relatively diverse alternatives that emphasize different perspectives than learning path based on relationships of concept maps and learning path based on "hyperlink network of 55 concepts" and arrive to different eternal cycles. There is a need for further experiments with much bigger samples to make more accurate estimates.

Table 6.9. Ten learning paths based on exploration paths in “hyperlink network of 55 concepts” starting from concept Human and proceeding to highest-ranking end concepts of departing hyperlinks or highest-ranking start concepts of arriving hyperlinks in respect to five alternative statistical features (hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and editing rate per article size) based on hyperlinks shown in Figure 6.3.

<p><i>Hierarchy of hyperlinks, along departing hyperlinks:</i> Human → Diet_(nutrition) → Organism → Biology → Organism (and then again to Biology thus forming an eternal cycle)</p> <p><i>Hierarchy of hyperlinks, along arriving hyperlinks:</i> Human ← Animal ← Birth ← Parent ← Father ← Parent (and then again to Father thus forming an eternal cycle)</p>
<p><i>Repetition of hyperlink terms, along departing hyperlinks:</i> Human → Religion → God → Religion (and then again to God thus forming an eternal cycle)</p> <p><i>Repetition of hyperlink terms, along arriving hyperlinks:</i> Human ← Religion ← God ← Religion (and then again to God thus forming an eternal cycle)</p>
<p><i>Article size, along departing hyperlinks:</i> Human → Oxygen → Sun → Oxygen (and then again to Sun thus forming an eternal cycle)</p> <p><i>Article size, along arriving hyperlinks:</i> Human ← Cat ← Dog ← Cat (and then again to Dog thus forming an eternal cycle)</p>
<p><i>Viewing rate, along departing hyperlinks:</i> Human → Love → Religion → Sun → Oxygen → Water → Sun (and then again to Oxygen thus forming an eternal cycle)</p> <p><i>Viewing rate, along arriving hyperlinks:</i> Human ← Cat ← Dog ← Cat (and then again to Dog thus forming an eternal cycle)</p>
<p><i>Editing rate, along departing hyperlinks:</i> Human → Old_age → Child → Old_age (and then again to Child thus forming an eternal cycle)</p> <p><i>Editing rate, along arriving hyperlinks:</i> Human ← Mother ← Birth ← Parent ← Mother (and then again to Birth thus forming an eternal cycle)</p>

In respect to traversing exploration paths in networks shown in Figure 6.3 it could be also possible to select paths so that highest-ranking concepts based on statistical features (shown in Table 6.3, Table 6.4, Table 6.5, Table 6.7 and Table 6.8) could be prioritized even when having distance longer than just one hyperlink. Therefore each concept could be considered metaphorically to have some kind of own gravitational field and the sum of all these gravitational fields would then contribute to selecting at each step the next hyperlink to be traversed next in the hyperlink network.

While exploring hyperlink chains, besides prioritizing the highest-ranking hyperlinks in respect to article statistics it can be sometimes useful to prioritize also hyperlinks having lower rankings or even the lowest rankings. We suggest that offering to the learner a flexible method to intuitively adjust what ranking range becomes prioritized would be practical.

6.4. Findings and their relation to the entity of the dissertation

The proposed method aims to suggest hyperlink chains that offer highest pedagogic value for the learner's exploration of hyperlink network of the Wikipedia. An essential strength of the method is the aim to provide a reasonable collection of alternative hyperlink chains that maintain semantic and educational relatedness between each step in the chain and between parallel chains. We think that this is based on four key factors: collaboratively maintained initial organization of concepts and relations (evolution of the Wikipedia), dynamic ranking in respect to five features supporting alternative perspectives (article statistics), illustrations denoting previous and current conceptual reasoning (concept maps), and letting the learner to make the ultimate decision for next step based on her intuition and consideration (support for variety of personalities).

The proposed method relies heavily on extraction and analysis of hyperlinks in Wikipedia articles related to a chosen learning topic. Recommendable learning paths are represented as a gradually expanding concept map that can be directly shown to the learner and also applied later in various educational purposes. The method aims to provide a balanced tradeoff between extensive coverage and compactness in the generated learning content. The method offers learning paths that should enable the learner to traverse the most essential knowledge in the least amount of time. This traversing can be exploited as means to adopt new knowledge or to refresh it. The traversed learning paths become documented as concept maps thus enabling the learner to analyse illustratively her conceptualization concerning a chosen topic. These knowledge structures can be easily further edited, reused and shared with other learners.

The publication [P3] presents a method naturally extending the method introduced in the publication [P2]. In the method of publication [P2] the learner was offered just a list of hyperlinks in the order of appearance for traversing in hyperlink network but the method of publication [P3] offers also retrieving statistics about Wikipedia articles to offer guidance for exploration in the knowledge structure of the Wikipedia. The exploration method is further extended in publication [P4] by describing how diverse statistics can be taken from the article's usage and edit history to enable the learner to better conceptualize alternative perspectives to the learning topic and their evolution along parallel exploration paths as well as to increase the pedagogical coverage about the learning topic. The exploration paths in the hyperlink network are expected to create concept maps defining useful learning processes. These pieces of knowledge need additional methods to be elaborated to achieve greater educational value. Addressing to this need, publication [P5] describes a wiki architecture to manage knowledge created with collective concept map building and publication [P6] describes a method to connect pieces of conceptual networks to relate the learner's prior knowledge to new knowledge.

Chapter 7. Generating personalized parallel learning paths from the Wikipedia with the latest hyperlink structure or its temporal evolution

In publication [P4] we propose a new method helping the learner to explore and analyze semantic relations between concepts represented by Wikipedia articles by building *parallel, branching learning paths* using adaptive lists and concept maps. We now here first explain basic idea and motivation about generating concept maps based on exploring the *latest version of Wikipedia hyperlink network* and its *temporal evolution*. Then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P4]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P4].

Figure 7.1 illustrates the main idea of the method proposed in publication [P4]. Similarly as in Figure 6.1, also in Figure 7.1 the hexagons represent crosslinked entity of articles of the Wikipedia online encyclopedia. We are extending the proposal made in publication [P3] that used statistics about the hyperlinked articles to create rankings for alternative traversing routes of hyperlinks between articles. Like previously, alternative rankings are represented by three parallel orderings based on Arabic numbers (1., 2., 3.,...), Latin alphabets (a., b., c.,...) and Roman numbers (I, II, III,...). However, instead of just one linear learning path, now we propose building parallel and branching learning paths covering alternative perspectives represented by articles. The learner's exploration path in the hyperlink network so far is shown by a chain of arrows.

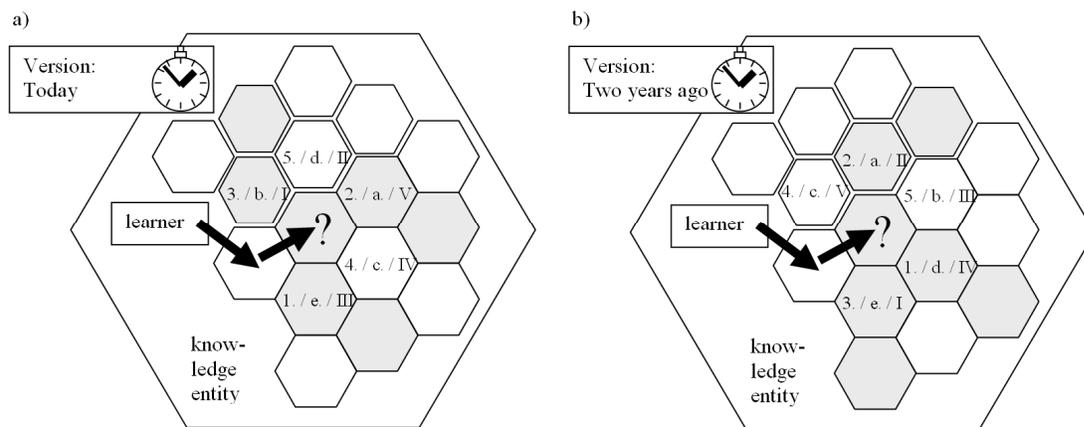


Figure 7.1. Main idea of the method proposed in publication [P4] for generating personalized learning paths from the Wikipedia based on the latest version of hyperlink structure of the Wikipedia (a) or its temporal evolution as illustrated with its two years old temporal version.

In Figure 7.1a, grayed hexagons indicate three possible chains of hyperlinks that the learner can traverse from current article (a hexagon indicated with a question mark) in respect to the latest version of Wikipedia hyperlink network. Each of these three chains is based on a chain of the highest-ranking hyperlinks in respect to one of three shown statistics and is expected to be traversed if learner decides to prioritize ranking values shown in Arabic numbers, Latin alphabets or Roman numbers. In addition, the proposed method also extends support to enable exploring hyperlink networks in any temporal version belonging to the history for the current article. In Figure 7.1b, grayed hexagons indicate three possible exploration paths relying on traversing hyperlinked articles that belong to a chosen temporal version of the hyperlink network based on ranking of article statistics from that same chosen historical moment in time (in this example, two years ago). Each of these three chains is based on a chain of the highest-ranking hyperlink in respect to one of three shown statistics. With different temporal versions of hyperlink networks and their respective rankings the learner can get a great variety of exploration paths to proceed.

7.1. Semantic exploration of network to support knowledge acquisition

Based on our earlier results presented in publication [P3] we identified a need to extend semantically motivated methodology for diverse personalized exploration in the hyperlink network of the Wikipedia. From previous research we found several promising results supporting to develop educational exploration further so that it enables adoption of knowledge through *comparable parallel perspectives* and *temporal versions* along evolution of knowledge structures.

Educational tools providing holistic solutions for everchanging learning scenarios are needed (Utz et al. 2009). As an intuitive medium, concept maps have been recommended for illustrating relationships of educational material in both flexible and compact form (Buzan & Buzan 2003). Knowledge maturing has been verified in the Wikipedia as implicit contextualized knowledge becomes gradually explicitly linked and formalized, and useful measures for maturing can possibly be extracted from creation and usage contexts (Braun & Schmidt 2007).

To exploit the maturing of Wikipedia for pedagogical exploration, our work is inspired by intelligent tutoring systems, content-based filtering, information retrieval and clustering. Weber et al. (2009) introduced a tool for visual semantic browsing and decision making based on concept maps. García-Plaza et al. (2008) proposed an unsupervised document representation model to cluster web pages with self-organizing maps using features of the pages. These works support us to develop map-based tool for exploration without extensive indexing of the Web.

Hyperlinks can be seen as a tagging about the article's context. Kamps and Koolen (Kamps & Koolen 2008) showed that the degree of arriving hyperlinks can be exploited to significantly improve effectiveness of ad hoc information retrieval. Zubiaga et al.

(2009) showed that socially annotated web content can be well classified based on weighted tags, even with limited user counts. Noll and Meinel (Noll & Meinel 2008) showed that tag-based classification seem to suit better to top-level documents in a hierarchy and deeper levels need contextual information mediated from higher levels. These results motivate us to recommend hyperlinks for exploration based on simple ranked statistics about articles that are hierarchically related or encountered earlier.

To address imprecision, Kotsakis (Kotsakis 2006) proposed querying XML documents with fuzzy ranking relying on Levenshtein distances based on tags encountered in paths and characters included in terms. Emphasizing document's structure, Cafarella et al. (2008) proposed querying relational information from HTML tables on the Web and ranking them in respect to diverse text-derived features. To integrate schema information from numerous structured data sources, Nandi and Bernstein (Nandi & Bernstein 2009) proposed a semi-supervised mapping method relying on a log of queries that cause click-throughs. The DBpedia (Bizer et al. 2009 (DBpedia)) is a promising project extracting structured factual information from Wikipedia articles to form an expressive dataset facilitating queries about relationships and properties. Chan et al. (2008) proposed a search algorithm over the DBpedia enabling to extract a semantic graph from Wikipedia's hyperlink structure. Another interesting effort to exploit the Wikipedia is semantic search engine NAGA (Kasneci et al. 2008) using graph-based query language with ranking that considers confidence, informativeness and compactness of results.

7.2. Building parallel branching learning paths with temporal versions of hyperlink network

The proposed method relies on using two alternative approaches for learning that are topological exploration mode and evolutionary exploration mode. In *topological exploration mode*, the learner proceeds in the network of hyperlinks belonging to the latest versions of Wikipedia articles. The hyperlinks are shown in a few parallel ranking lists providing alternative rankings sorted in decreasing order of significance. Based on distinct ranking criteria, each list promotes hyperlinks representing a different pedagogical perspective to the learning topic. Despite of relying on our earlier method introduced in publication [P3], now in topological exploration the learner's exploration is expected to give a specific emphasis for building comparable parallel learning paths instead of traversing just linear learning paths.

From the ranking lists the learner selects a desired amount of concepts that seem promising for her, indicating what perspectives she wants to be prioritized by the method in further exploration. Selected concepts and their relations to previous concepts become illustrated in a progressively expanding concept map. Nodes labeled with the concepts are connected with directed arcs labeled with relation statements respectively. From the concept map the learner selects one concept for the next step in exploration and from now on each ranking list shows hyperlinks for the article corresponding to this selected concept. By repeating this cycle, step by step, new hyperlinks with alternative

rankings are constantly recommended by the method thus providing a diversity of parallel and branching exploration paths. Based on her needs and intuition, the learner explores hyperlink network and meanwhile the method builds automatically a concept map that reflects her conceptualization process and enables comparing simultaneously alternative perspectives to the learning topic based on parallel learning paths.

We suggest that ranking of hyperlinks should rely on simple statistics concerning current article and target article. Based on convincing results in our previous work [publication [3]], reflecting five main functions identified for the Wikipedia, we decided to use following measurable parameters as ranking criteria for hyperlinks: order of hyperlinks in current article, hyperlinks whose target article's titles are most repeated in current article, size of hyperlink's target article, view rate of hyperlink's target article and edit rate of hyperlink's target article. These measures can be easily retrieved from revision history and online services providing Wikipedia statistics, and relation statements can be extracted from sentences surrounding hyperlinks with a parsing method, as explained in our previous work in publication [P2] and publication [P3].

In *evolutionary exploration mode* a concept and its relations can be represented by any previous temporal version of the corresponding Wikipedia article and its hyperlinks at that time. The learner is provided with a simple dial to select a desired time frame from the revision history of current article. Also the ranking of hyperlinks is carried out with statistics from the same chosen historical moment in time. The learner can browse consecutive temporal versions of articles to see how new hyperlinks and relation statements are introduced and how older ones become edited or even removed. By observing these temporal transformations the learner can get insight how conceptualization can proceed in a collaborative environment. By alternating between both evolutionary and topological exploration modes, the learner should receive even additional pedagogical advantage as she simultaneously gives attention to both temporal local emergence of knowledge clusters and general connectivity among clusters in relations fixed to a certain time frame.

We propose two optional enhancements for the method that are definition boost and memory effect. *Definition boost* lets the learner to see only those hyperlinks belonging to the introduction section of current article, typically located before the table of contents. Since writing style in introduction is often more definitive than later in the article, also recommended hyperlinks are expected to emphasize now more definitions. *Memory effect* gives extra promotion to hyperlinks that are shared among concepts added so far to the concept map. If at least two previously encountered articles have the same target article as the current article has, this hyperlink will be automatically given a leading position in the ranking lists.

Figure 7.2 (originally published as Figure 1 in publication [P4]) shows a concept map generated with the topological exploration mode starting from Wikipedia article "History of the world" based on the latest version of hyperlink network at the time of writing publication [P4], in January 2010. For each node the linked nodes are based on the highest-ranking hyperlinks, shown in descending order of significance from left to right, while the ranking criteria is based on sum of all five statistical features discussed above. Definition boost was applied on all levels and memory effect was applied only to

generate the nodes of third level. Figure 7.2 shows stubs of concept maps generated with evolutionary exploration mode based on three time frames of article “History of the world” in January 2008 (b), January 2009 (c) and January 2010 (d) with similar conditions for linking nodes as described for the example of topological exploration (a).

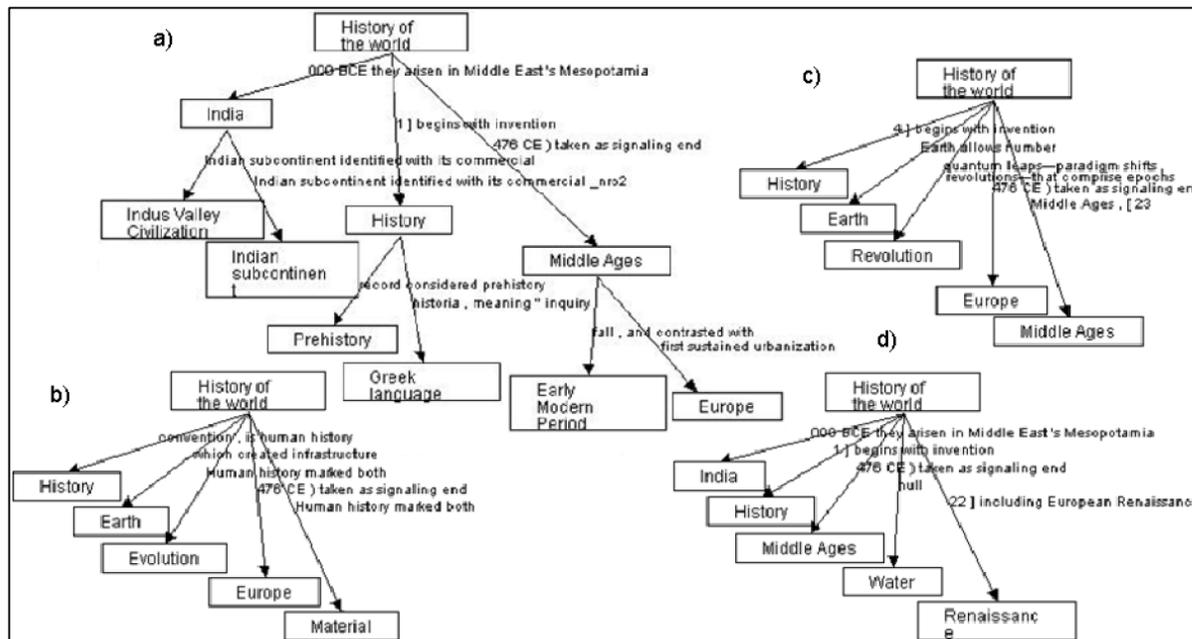


Figure 7.2 (originally published as Figure 1 in publication [P4]). Concept map produced with topological exploration about topic “History of the world” in January 2010 (a). Stubs of concept maps produced with evolutionary exploration about topic “History of the world” with three time frames: January 2008 (b), January 2009 (c), and January 2010 (d).

We carried out experiments to evaluate educational gain of the proposed method. We compared the conceptual structures generated with our method to corresponding established learning material. Comparative analysis done in the context of learning topic of world history showed that learning paths generated with the proposed method in the hyperlink network of the Wikipedia matched well with corresponding learning paths gained when accessing four main periods of history through index of a children’s world history book (Adams 2008).

We made further analysis to get better understanding about *temporal evolution* of hyperlink network of the Wikipedia. Table 7.1 shows Wikipedia articles corresponding to 102 core concepts, from word lists generated by students, listed in chronological order in respect to the creation date of the Wikipedia article.

Table 7.2 offers a comparison of rankings based on *creation date of Wikipedia article*, *occurrences in word lists of students* and *sum of measures of importance given by students* in respect to 55 concepts belonging to “hyperlink network of 55 concepts” when ranking values have been transformed to an equal ranking scale 1–55.

Table 7.1. Wikipedia articles corresponding to 102 core concepts, from word lists generated by students, listed in chronological order in respect to the creation date of the Wikipedia article. Articles created on same day are supplied with suffixes (a, b, c etc.) to indicate their more detailed chronological order, we were not able to find difference in creation time for Health and Pet which both had same creation time at accuracy level of one minute.

<i>Concept</i>	<i>Creation date</i>	<i>Concept</i>	<i>Creation date</i>	<i>Concept</i>	<i>Creation date</i>
Leisure	20010129	Television	20011104	Parent	20020910c
Animal	20010329	Sport	20011105	Birth	20020910d
Plant	20010508	Evolution	20011106a	Adolescence	20020911
Shoe	20010521	Biology	20011106b	Child	20021023
Sea	20010528	Education	20011107	Travel	20021208
Book	20010606	Party	20011108	Future	20021230
Water	20010727	Cat	20011109	Childhood	20030109
Love	20010817	Light	20011110	Pleasure	20030115a
Tree	20010904	Sun	20011111	Happiness	20030115b
Forest	20010909	Marriage	20011112a	Learning	20030215
School	20010910	Music	20011112b	Joy	20030221
Money	20010911	City	20011113	Atmosphere_of_Earth	20030329
Oxygen	20010915	Religion	20011117	Teacher	20030403
Disease	20010919	Hobby	20011118	Eating	20030419
Clock	20010920	Peace	20011122	Test_(assessment)	20030505
Food	20010927	Summer	20011230	Old_age	20030518
Friendship	20010929	Emotion	20020112	Sadness	20030527
Telephone	20010930a	Rain	20020120	Home	20030619
Work	20010930b	Heart	20020127	Chair	20030707
Human	20011003	Bread	20020129a	Experience	20030816
Dog	20011006	Environment	20020129b	Sorrow	20030823
House	20011011	Family	20020204	Sibling	20031029
War	20011015	Clothing	20020207	Growing	20031222
Management	20011016	World	20020211a	Ground	20040113
Death	20011018	Flower	20020211b	Physical_fitness	20040116
Nature	20011025	Health	20020225 (same time shared with Pet)*	Purpose	20040315
God	20011028	Pet	20020225 (same time shared with Health)*	Diet_(nutrition)	20040507
Paper	20011030	Dream	20020318	Study	20040517
Philosophy	20011031a	Fun	20020325	Bed	20040902
Time	20011031b	Hospital	20020803	Living	20041105
Automobile	20011101a	Infant	20020818	People	20051221
Holiday	20011101b	Pen	20020825	Goodness	20060222
Computer	20011102a	Father	20020910a	Hatred	20060911
Organism	20011102b	Mother	20020910b	Goal	20071223

Table 7.2. Comparison of rankings based on creation date of Wikipedia article, occurrences in word lists of students (n=103) and sum of measures of importance given by students (n=103), in respect to 55 concepts belonging to “hyperlink network of 55 concepts”, ranking values transformed to an equal ranking scale 1–55.

Concept	Ranking based on creation date of Wikipedia article	How many positions higher is ranking based on occurrences in word lists of students	How many positions higher is ranking based on sum of measures of importance given by each student	Concept	Ranking based on creation date of Wikipedia article	How many positions higher is ranking based on occurrences in word lists of students	How many positions higher is ranking based on sum of measures of importance given by each student
Leisure	1	-33.5s	-27.5s	Light	29	-5.5s	-9.5s
Animal	2	-7s	-10s	Sun	30	+15s	+15s
Plant	3	-19s	-18s	Music	31	+0.5s	+2.5s
Sea	4	-36s	-43s	Religion	32	+1.5s	-10s
Water	5	-2.5s	0s	Peace	33	-12s	-4
Love	6	+0.5s	+3	Emotion	34	-6s	+4s
Tree	7	-17s	-24s	Heart	35	-5s	+1.5s
School	8	+2.5s	0s	Family	36	+35s	+35s
Oxygen	9	-42.5s	-26s	Clothing	37	+2.5s	+10s
Disease	10	-30s	-44s	Health	38s	+18.5s	+24s
Food	11	+3.5s	+5s	Pet	38s	+3.5s	-3s
Friendship	12	+10s	+10s	Father	39	+4.5s	+15s
Telephone	13	-38.5s	-35s	Mother	40	+12s	+18s
Work	14	+11s	+10s	Parent	41	-10.5s	+5s
Human	15	+5s	+6s	Birth	42	+31s	+32s
Dog	16	-1.5s	-7s	Adolescence	43	-2s	-10
House	17	-0.5s	-3s	Child	44	+29s	+28s
War	18	-27s	-37	Travel	45	-6.5s	+6.5s
Death	19	+15s	+12s	Happiness	46	+22s	+28s
Nature	20	+8s	+9s	Learning	47	+19s	+22s
God	21	-24s	-24.5s	Joy	48	+33s	+31s
Automobile	22	-2s	-11.5s	Teacher	49	-2.5s	-2s
Computer	23	+2s	-3s	Old_age	50	+15.5s	+6s
Organism	24	-27.5s	-26s	Home	51	+38s	+38s
Television	25	-3s	-7s	Experience	52	+12s	+12s
Biology	26	-19s	-23s	Sibling	53	+1.5s	+1
Education	27	+7.5s	+8	Diet (nutrition)	54	+2.5s	+11s
Cat	28	+2s	-17.5s				
<i>(the listing continues on the fifth column of this table)</i>							

Based on Table 7.2 for each of three comparison tests Table 7.3 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating degrees of dependency between three rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to creation date of Wikipedia article, occurrences in word lists of students and sums of measures of importance given by students.

Table 7.3. Degrees of dependency between three rankings of 55 concepts of “hyperlink network of 55 concepts” in respect to creation date of Wikipedia article, occurrences in word lists of students (n=103) and sums of measures of importance given by students (n=103).

Compared pair of distributions		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
creation date of Wikipedia article for each of 55 concepts	occurrences in word lists of students for each of 55 concepts (n=103)	gamma=0.2380952 (standard error 0.1920267); null hypothesis Hgk not rejected (p=0.2150099)	rho=0.321374; null hypothesis Hsr rejected (p=0.01674)	tau=0.2317536; null hypothesis Hkr rejected (p=0.01464)
creation date of Wikipedia article for each of 55 concepts	sums of measures of importance given by students for each of 55 concepts (n=103)	gamma=0.1540541 (standard error 0.1904736); null hypothesis Hgk not rejected (p=0.4186333)	rho=0.2380446; null hypothesis Hsr not rejected (p=0.0801)	tau=0.1537943; null hypothesis Hkr not rejected (p=0.09784)
occurrences in word lists of students for each of 55 concepts (n=103)	sums of measures of importance given by students for each of 55 concepts (n=103)	gamma=0.7863248 (standard error 0.1222799); null hypothesis Hgk rejected (p=1.271583×10 ⁻¹⁰)	rho=0.9042751; null hypothesis Hsr rejected (p<2.2×10 ⁻¹⁶)	tau=0.7645224; null hypothesis Hkr rejected (p=8.882×10 ⁻¹⁶)

Table 7.4 shows some of the greatest and smallest ranking differences for rankings based on creation date of Wikipedia article, occurrences in word lists of students and sum of measures of importance, in respect to 55 concepts belonging to “hyperlink network of 55 concepts”. It appears that concepts having higher ranking position for occurrences in word lists generated by students or for sum of measures of importance given by each student than for creation date of Wikipedia article include for example Home, Family, Joy, Birth and Child. In addition, concepts having higher ranking position for creation date of Wikipedia article than for occurrences in word lists generated by students or for sum of measures of importance given by each student include for example Sea, Disease, Telephone and Leisure.

Concepts in hyperlink network of the Wikipedia have a varying emphasis in respect to what is the balance of departing and arriving hyperlinks they have. We think that analysis about balance of departing and arriving hyperlinks can fruitfully help to gain better understanding and modeling about how in conceptual networks such exploration paths could be identified that are educationally most rewarding to become explored by a student. To enable analysing the role of each concept has in respect to *balance of departing and arriving hyperlinks* Table 7.5 shows difference between the number of departing hyperlinks and the number of arriving hyperlinks inside hyperlink network of 102 core concepts and inside “hyperlink network of 55 concepts”, shown in decreasing order of size of difference.

It seems to us that there can be some general characteristics about a concept that affects the balance of its departing and arriving hyperlinks. If trying to coarsely contrast opposite sides, it seems that a Wikipedia article that has more departing hyperlinks than arriving hyperlinks can perhaps be considered to represent topics that remain on relatively informal level of language whereas a Wikipedia article that has less departing hyperlinks than arriving hyperlinks can perhaps be considered to represent topics that deal with systematical classification. This hypothesis seems to get some support when comparing conceptual pairs about approximately same topic that have contrasting emphasis in balance of departing and arriving hyperlinks, for example in respect to hyperlink network of 102 core concepts Nature has a positive balance value 5 (10-5=5)

whereas Organism has negative balance value -6 (4-10=-6), and furthermore Animal has neutral balance value 0 (10-10=0). It seems that limiting analysis to a smaller hyperlink network containing only 55 concepts instead of 102 concepts can cause changes in balance of departing and arriving hyperlinks, for example Birth gets higher relative position in ranking based on balance value in network of 55 concepts than in network of 102 concepts, and similarly Oxygen gets lower position in ranking.

Table 7.4. Some of the greatest and smallest ranking differences for 55 concepts belonging to “hyperlink network of 55 concepts” in respect to occurrences in word lists generated by students (n=103) versus creation date of Wikipedia article, and in respect to sum of measures of importance given by each student (n=103) versus creation date of Wikipedia article, ranking values transformed to equal ranking scale 1–55.

Comparison between creation date of Wikipedia article and occurrences in word lists of students			Comparison between creation date of Wikipedia article and sum of measures of importance given by students		
Some of the greatest ranking differences for concepts having higher ranking position for occurrences in word lists generated by students than for creation date of Wikipedia article	Some of the greatest ranking differences for concepts having lower ranking position for occurrences in word lists generated by students than for creation date of Wikipedia article	Some of the smallest ranking differences for concepts between ranking based on occurrences in word lists generated by students and creation date of Wikipedia article	Some of the greatest ranking differences for concepts having higher ranking position for sum of measures of importance given by each student than for creation date of Wikipedia article	Some of the greatest ranking differences for concepts having lower ranking position for sum of measures of importance given by each student than for creation date of Wikipedia article	Some of the smallest ranking differences for concepts between ranking based on sum of measures of importance given by each student and creation date of Wikipedia article
Home (+38s)	Oxygen (-42.5s)	Love; Music (+0.5s)	Home (+38s)	Disease (-44s)	School; Water (0s)
Family (+35s)	Telephone (-38.5s)	House (-0.5s)	Family (+35s)	Sea (-43s)	Sibling (+1)
Joy (+33s)	Sea (-36s)	Religion; Sibling (+1.5s)	Birth (+32s)	War (-37)	Heart (+1.5s)
Birth (+31s)	Leisure (-33.5s)	Dog (-1.5s)	Joy (+31s)	Telephone (-35s)	Teacher (-2s)
Child (+29s)	Disease (-30s)	Cat; Computer (+2s)	Child; Happiness (+28s)	Leisure (-27.5s)	Music (+2.5s)
		Adolescence; Automobile (-2s)			

We think that the *chronological order of adding new hyperlinks* to a Wikipedia article can offer useful insight about how humans prioritize certain relationships when they collectively gradually build a hyperlink network cross-linking various concepts.

Table 7.6 shows three chronologically first hyperlinks added before March 2005 to Wikipedia articles corresponding to 102 core concepts that link to an article corresponding to any of 102 core concepts. Based on Table 7.6, four lists in Table 7.7 summarizes most occurring concepts among three first added hyperlinks and only in the first added hyperlink, and enables to contrast observation inside hyperlink network of 102 core concepts and observation inside “hyperlink network of 55 concepts”. Although differences are small, highest-ranking concepts seem to deal a lot with topics related to religion and nature, and when limiting analysis from the first three hyperlinks to only the first hyperlink seems to increase occurrences of Human and when limiting vocabulary from 102 to 55 concepts seems increase occurrences of Education.

Table 7.5. Difference between the number of departing hyperlinks and the number of arriving hyperlinks inside hyperlink network of 102 core concepts and inside “hyperlink network of 55 concepts”, shown in decreasing order of size of difference. Duplicates have been eliminated from the number of hyperlinks (i.e. if a Wikipedia article contains several hyperlinks pointing to a certain other Wikipedia article only one occurrence of this hyperlink is counted).

Inside hyperlink network of 102 core concepts (* = concept belongs to “hyperlink network of 55 concepts”)				Inside “hyperlink network of 55 concepts”	
Concept	How much more departing hyperlinks than arriving hyperlinks	Concept	How much more departing hyperlinks than arriving hyperlinks	Concept	How much more departing hyperlinks than arriving hyperlinks
Hobby	8 (8-0)	Goodness	0 (0-0)	Food	9 (10-1)
Food*	7 (12-5)	Ground	0 (0-0)	Human	5 (16-11)
Human*	6 (20-14)	Growing	0 (0-0)	Education	4 (10-6)
Atmosphere_of_Earth	5 (9-4)	Holiday	0 (0-0)	Birth	3 (4-1)
Nature*	5 (10-5)	Hospital	0 (2-2)	Nature	3 (7-4)
Education*	4 (13-9)	Living	0 (0-0)	Death	2 (7-5)
Pleasure	4 (7-3)	Management	0 (0-0)	Friendship	2 (3-1)
Test_(assessment)	4 (4-0)	Sea*	0 (1-1)	Home	2 (3-1)
Bed	3 (3-0)	Study	0 (0-0)	House	2 (4-2)
Birth*	3 (4-1)	War*	0 (4-4)	Mother	2 (7-5)
Bread	3 (4-1)	Adolescence*	-1 (7-8)	Parent	2 (6-4)
Death*	3 (9-6)	Dream	-1 (0-1)	Water	2 (8-6)
Friendship*	3 (4-1)	Experience*	-1 (2-3)	Cat	1 (3-2)
Mother*	3 (8-5)	Goal	-1 (1-2)	Child	1 (6-5)
Party	3 (3-0)	Health*	-1 (5-6)	Clothing	1 (2-1)
People	3 (4-1)	Joy*	-1 (1-2)	Computer	1 (2-1)
Sadness	3 (6-3)	Marriage	-1 (8-9)	Dog	1 (3-2)
Child*	2 (9-7)	Rain	-1 (3-4)	Emotion	1 (4-3)
City	2 (3-1)	School*	-1 (2-3)	God	1 (3-2)
Clock	2 (3-1)	Sorrow	-1 (0-1)	Leisure	1 (5-4)
Eating	2 (5-3)	Telephone*	-1 (0-1)	Light	1 (2-1)
Emotion*	2 (8-6)	Travel*	-1 (0-1)	Music	1 (2-1)
Forest	2 (4-2)	Work*	-1 (0-1)	Old_age	1 (4-3)
Home*	2 (3-1)	Automobile*	-2 (1-3)	Peace	1 (2-1)
Learning*	2 (4-2)	Biology*	-2 (9-11)	Teacher	1 (3-2)
Leisure*	2 (8-6)	Childhood	-2 (4-6)	Tree	1 (2-1)
Parent*	2 (6-4)	Future	-2 (0-2)	Automobile	0 (1-1)
Purpose	2 (4-2)	God*	-2 (4-6)	Diet_(nutrition)	0 (4-4)
World	2 (2-0)	Oxygen*	-2 (9-11)	Father	0 (5-5)
Cat*	1 (3-2)	Paper	-2 (2-4)	Health	0 (4-4)
Clothing*	1 (4-3)	Sibling*	-2 (6-8)	Learning	0 (2-2)
Dog*	1 (3-2)	Sport	-2 (1-3)	Pet	0 (3-3)
Father*	1 (6-5)	Heart*	-3 (0-3)	Plant	0 (8-8)
House*	1 (4-3)	Music*	-3 (3-6)	Sea	0 (1-1)
Infant	1 (6-5)	Physical_fitness	-3 (0-3)	Animal	-1 (7-8)
Light*	1 (3-2)	Disease*	-4 (1-5)	Joy	-1 (1-2)
Love*	1 (11-10)	Plant*	-4 (12-16)	Love	-1 (6-7)
Money	1 (2-1)	Time	-4 (8-12)	School	-1 (2-3)
Old_age*	1 (6-5)	Evolution	-5 (5-10)	Telephone	-1 (0-1)
Peace*	1 (2-1)	Happiness*	-5 (2-7)	Travel	-1 (0-1)
Pen	1 (1-0)	Hatred	-5 (0-5)	War	-1 (3-4)
Pet*	1 (4-3)	Sun*	-5 (2-7)	Work	-1 (0-1)
Shoe	1 (1-0)	Family*	-6 (6-12)	Adolescence	-2 (4-6)
Summer	1 (1-0)	Organism*	-6 (4-10)	Experience	-2 (0-2)
Teacher*	1 (4-3)	Religion*	-7 (5-12)	Happiness	-2 (2-4)
Tree*	1 (3-2)	Television*	-10 (0-10)	Sibling	-2 (5-7)
Water*	1 (10-9)	Philosophy	-11 (3-14)	Biology	-3 (6-9)
Animal*	0 (10-10)			Disease	-3 (1-4)
Book	0 (2-2)			Heart	-3 (0-3)
Chair	0 (0-0)			Oxygen	-3 (6-9)
Computer*	0 (2-2)			Organism	-4 (3-7)
Diet_(nutrition)*	0 (4-4)			Religion	-4 (3-7)
Environment	0 (0-0)			Sun	-4 (2-6)
Flower	0 (2-2)			Family	-5 (5-10)
Fun	0 (0-0)			Television	-7 (0-7)
<i>(the listing continues on the third column of this table)</i>					

Table 7.6 part 1 of 2 (starts here and continues on next page). Three chronologically first hyperlinks added before March 2005 to Wikipedia articles corresponding to 102 core concepts that link to an article corresponding to any of 102 core concepts.

Wikipedia article	Three chronologically first hyperlinks added before March 2005 that link to an article corresponding to any of 102 core concepts (* = several hyperlinks added at the same time in one instance of article revision; p = previous instance of article revision included already this second/third hyperlink; x = no hyperlinks added before March 2005)		
<i>Article title (concept)</i>	<i>First hyperlink</i>	<i>Second hyperlink</i>	<i>Third hyperlink</i>
Adolescence	Child	Education; School	p
Animal	Human	Cat; Dog *	p
Atmosphere of Earth	Oxygen; Sun *	p	Rain
Automobile	Travel		
Bed	Infant		
Biology	Evolution	Environment; Organism *	p
Birth	Death; Mother *	p	Sun
Book	Paper		
Bread	Food; Water *	p	
Cat	Dog	Pet	Rain
Chair	Music		
Child	Human	Parent	Tree
Childhood	Child		
City	Religion		
Clock	Time	Computer	
Clothing	Animal	God	Shoe
Computer	Telephone	Clock	
Death	Heart	Birth	Religion
Diet (nutrition)	Food		
Disease	Biology		
Dog	Pet	Death	Cat
Dream	God	Experience	
Eating	Food		
Education	Family	School	Child
Emotion	Joy; Sadness *	p	
Environment	Biology	Light; Water *	p
Evolution	Biology	God	Organism
Experience	Time		
Family	Marriage	Father; Mother *	p
Father	Mother	Marriage	Family
Flower	Plant	Death; Love *	p
Food	Animal; Plant *	p	Bread
Forest	Tree		
Friendship	x		
Fun	x		
Future	Death; Evolution; God; Human; Philosophy; Religion; Time *	p	p
Goal	x		
God	Philosophy	Evolution	
Goodness	Sun		
Ground	Philosophy	Music	
Growing	x		
Happiness	Money	Family; Food; Learning; Love; Philosophy; Religion *	p
Hatred	x		
Health	Human; Organism *	p	Biology
Heart	Oxygen; Water *	p	Animal
Hobby	Sport		

Table 7.6 part 2 of 2 (started on previous page and continues here).

Wikipedia article	Three chronologically first hyperlinks added before March 2005 that link to an article corresponding to any of 102 core concepts (* = several hyperlinks added at the same time in one instance of article revision; p = previous instance of article revision included already this second/third hyperlink; x = no hyperlinks added before March 2005)		
<i>Article title (concept)</i>	<i>First hyperlink</i>	<i>Second hyperlink</i>	<i>Third hyperlink</i>
Holiday	Travel	Religion	Summer
Home	x		
Hospital	Disease	Health	
House	Human	Music	Animal
Human	Evolution	Cat; Child; Environment *	p
Infant	Child	Health	Birth
Joy	Happiness	Emotion	
Learning	Education		
Leisure	Sport	Education	
Light	Time	Sun	
Living	x		
Love	Emotion	Family	God
Management	x		
Marriage	Religion	Family	Emotion
Money	Paper	Bread	
Mother	Father	Child; Parent *	p
Music	Television	Religion	
Nature	Biology	God	Education
Old age	Death	Biology	
Organism	Animal; Biology; Plant *	p	p
Oxygen	Water	Plant	
Paper	Tree	Book	Forest
Parent	x		
Party	Family; Holiday *	p	Marriage
Peace	War		
Pen	x		
People	x		
Pet	Cat; Dog *	p	People
Philosophy	Goodness	God; Time *	p
Physical fitness	Health		
Plant	Flower; Tree *	p	Organism
Pleasure	Happiness		
Purpose	x		
Rain	Water	Sun	
Religion	God	War	Philosophy
Sadness	x		
School	Education	Learning	
Sea	x		
Shoe	Clothing; Home *		
Sibling	x		
Sorrow	x		
Sport	x		
Study	x		
Summer	x		
Sun	Oxygen	Water	
Teacher	Education; School *	p	
Telephone	Ground		
Television	Computer		
Test (assessment)	Education	Computer	Music; Teacher *
Time	Clock	Leisure; Travel *	p
Travel	x		
Tree	Forest; Religion; Water *	p	p
War	Religion	Peace	Philosophy
Water	Sea	Biology	Oxygen
Work	x		
World	Religion	Philosophy	Birth

Table 7.7. Most occurring concepts among three first added hyperlinks and only in the first added hyperlink when observed inside hyperlink network of 102 core concepts and “hyperlink network of 55 concepts”.

Inside hyperlink network of 102 core concepts		Inside “hyperlink network of 55 concepts”	
<i>Most occurring concepts among three first added hyperlinks</i>	<i>Most occurring concepts only in the first added hyperlink</i>	<i>Most occurring concepts among three first added hyperlinks</i>	<i>Most occurring concepts only in the first added hyperlink</i>
Religion (10)	Religion (6)	Biology; Education; Religion (6)	Human (4)
Biology; God (8)	Biology; Human; Water (5)	Animal (5)	Animal; Biology; Education; Religion; Water (3)
Education; Philosophy; Water (7)	Education; Time (4)	Cat; Child; Family; God; Human; Water (4)	Death; Dog; Mother; Oxygen; Plant (2)

7.3. Findings and their relation to the entity of the dissertation

In our previous work discussed in publication [P3] we identified usefulness of supporting the learner’s exploration in the hyperlink network of the Wikipedia by ranking hyperlinks in respect to the article’s usage and edit history. We previously noted the advantage of generating alternative hyperlink chains that maintain semantic and educational relatedness between each step in the chain and between parallel chains. Now in publication [P4] we want to incorporate simultaneous visualization and exploration of parallel hyperlink chains paths for the actual learning process in adoption of knowledge.

Even a short chain of hyperlinks in the Wikipedia can cover essential knowledge about a desired educational topic. Due to rich variety of contributors, the hyperlink network of the Wikipedia combines numerous individually favored relations between concepts into one browsable entity. However, it is hard to define requirements for optimal exploration paths that can be favorably personalized in diverse contexts and generated with limited computational load. Results of related research that has been discussed earlier in this Chapter 7 (as well as in publication [P4]) has indicated that simple quantitative semi-automatic methods can be successfully used for measuring matching with imprecise queries to rank documents in a collection. This suggests that desired educational perspectives can be efficiently promoted by chaining ranked hyperlinks that have even relatively imprecise correlation between a simple statistical feature of current and target article. To enable holistic adaptive conceptualization process, the learner needs interactive knowledge representations and concept maps seem to offer an efficient medium for compact yet flexible illustrations. By approaching the learning topic simultaneously along parallel alternative exploration paths, the learner is expected to acquire rich complementing perspectives to adopt new knowledge.

Besides exploring just the relations between the latest versions of articles, browsing consecutive temporal versions of an article enables analyzing emergence of knowledge clusters. Two additional options enable to favor hyperlinks that have previously

encountered target articles and hyperlinks that promote definitions. Initial experiments with a prototype indicate that proposed functional principles can fruitfully support exploration that is sustainable for human learning.

We think that publication [P4] continues the development of method introduced in publication [P3] like that work was an extension from the method of publication [P2]. This development relies on suggesting certain statistics as guidance for exploration but we think that our proposal should be seen as a promising example for broader generalizations as well to achieve increased pedagogic coverage on educational exploration.

The method of publication [P4] can be seen as an attempt to form general approach for constructing educational knowledge in the form of concept maps by taking inspiration from the knowledge structure of the Wikipedia.

Along research of publication [P4] we identified a need for future research to address agglomeration of separate learning tasks and complementing methods of collaboration. We considered that easy evaluation and intervention methods are needed for teachers and furthermore personal learning styles and special needs should be strongly supported with encouragement and inspiration. Motivated by these notions we decided to augment the method of publication [P4] by introducing in publication [P5] a wiki architecture that helps to agglomerate individually created pieces of knowledge and in publication [P6] a method to find the shortest paths between pieces of knowledge between the learner's knowledge and the learning objective with support from learning context.

Part IV. Connecting and agglomerating entities of collaborative knowledge resources based on personal contributions

Chapter 8. A wiki framework to support collaborative knowledge building process with concept maps

In publication [P5] we propose a new educational framework, ConceptMapWiki, to generate collaboratively *reusable evolving knowledge resources* for education based on an inter-connected diverse collection of partially overlapping *concept maps*, thus forming shared ontologies. ConceptMapWiki is a wiki based on a method representing knowledge with adaptive concept maps that are collaboratively created, edited and browsed according to various learner-driven criteria for many educational purposes, supplied with collaboratively defined and evaluated learning paths.

We now here first explain basic idea and motivation about using a collaborative *educational wiki framework* for building collection of concept maps and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P5]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P5]. Figure 8.1 illustrates the main idea of the method proposed in publication [P5].

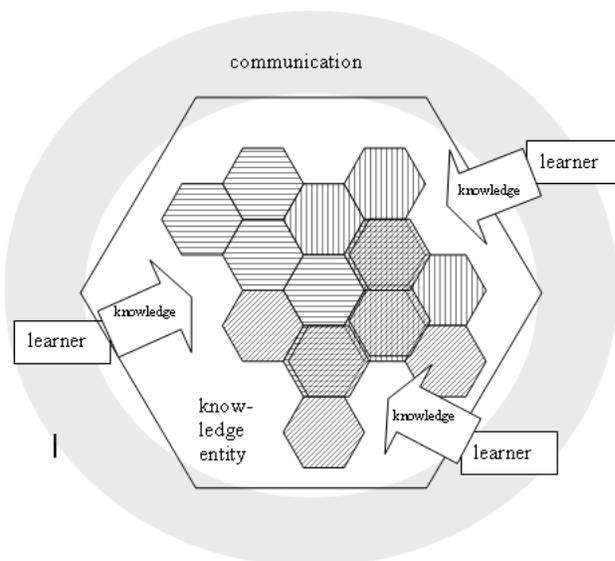


Figure 8.1. Main idea of the method proposed in publication [P5] for wiki framework to support collaborative knowledge building process with concept maps.

Similarly as in Figure 4.1, also in Figure 8.1 the linked hexagons together represented a collectively generated conceptual network. However now this network is not anymore a single concept map but instead a collectively gradually built collection of concept maps. Each joint group of hexagons indicated with a line pattern in specific direction (horizontal, vertical or ascending diagonal) represents a concept map created by a single collaborating learner. Overlapping concept maps introduce some hexagons having several concurrent line patterns. The collaborating learners contribute by building and editing together a progressively growing, complementing and finetuning knowledge entity of conceptual network. Communication is carried out between all collaborators to agree about actions to be taken during the building process.

Motivated by the methods introduced in publications [P2], [P3] and [P4] to guide educational exploration in hyperlink network of the Wikipedia, we identified that similar approach could be fruitfully applied with collaboratively built concept map collection. As an additional advantage, the proposal of publication [P5] seemed to usefully enable to developing collaborative framework addressing needs we had identified in publication [P1].

8.1. Collective construction of knowledge structures

Collaborative construction of concept maps has been shown to assist learning knowledge structures (Schaal et al. 2009) and efficient graph-theoretic reasoning algorithms enable relating general problem solving processes to fundamental problems in computer science (Chein & Mugnier 2009). Also graph-based clustering schemes have been used to identify groups of related tags in folksonomies (Papadopoulos et al. 2010). Since emerging in both social networks and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009), small-world networks are a promising structure for representing educational knowledge. Methods developed to model and explore knowledge in the Wikipedia give inspiration for developing pedagogically motivated knowledge repositories based on resembling wiki frameworks to support collaboratively various personalized learning tasks as discussed in publication [P4] and Chapter 7. Having over 4.3 million articles (as of June 2013) in English, more than concepts in a typical human vocabulary (Moore & ten Bosch 2009), the full content of Wikipedia cannot be effectively evaluated all the time (Milne 2009) and thus it seems reasonable to generate guidance for exploration by evaluating only few steps further in the knowledge network.

Learners should be enabled to retrieve personalized information with semantically enriched models (Zhuhadar et al. 2009). When different parties provide mappings with typed links between data, semantic cohesion can increase thus enabling data integration on global scale (Bizer et al. 2009 (Linked Data)). For example, Semantic MediaWiki enables annotating wikis with semantic data and OntoWiki offers intuitive authoring and navigating of RDF-based knowledge bases. 24 basic and compound evolution patterns of the knowledge engineering process have been identified for knowledge bases in the semantic web (Rieß et al. 2010). Ontology evolution has been guided by pattern

modeling and quality evaluation (Djedidi & Aufaure 2010) and ontology mapping has been used for open-corpus personalization in students' knowledge assessments (Sosnovsky 2009). Ontologies can be used for modeling educational modules (Borges & Barbosa 2009) and a collaborative environment using shared ontologies can be explored with concept maps (Leblanc & Abel 2009). Standardized concept map representation Topic Maps can address knowledge resources on multiple levels (Li et al. 2010) and enable forming an ontology for acquired knowledge in a lifelong learning perspective (Lavik et al. 2006). Using a wiki visualized with Topic Maps test users went through significantly less irrelevant information and pages than with a traditional wiki (Espiritu et al. 2006). An interactive workspace can integrate real-time synchronized wiki collaboration in knowledge-building activities based on concept mapping (Baraldi et al. 2006). There are many semi-automatic approaches to build concept maps (Kowata et al. 2010).

8.2. Wiki of concept maps for pedagogic knowledge management

In publication [P5] we propose a wiki based on method of representing knowledge collaboratively with concept maps. The method relies on contributions from individual learners and educators generating educational content by drawing concept maps into a graphic Java-driven user interface with an aim to capture some core semantic meanings of the learning topic relatively intuitively and spontaneously. Each step of creating, editing or browsing a concept map are recorded via Java Database Connectivity (JDBC) interface in a compact text format into a relational MySQL database as *concept map objects* with time stamps and a user profile, containing background information about the contributor's role, gender, age, educational level and experience in current topic. All the concept map objects together form a *concept map collection* that cumulatively matures due to collaborative editing and can be explored and exploited by the learners in various personalized guided learning activities addressing various perspectives and levels of detail.

Figure 8.2 (originally published as Figure 1 in publication [P5]) shows an example how concept maps and learning paths can be represented to the learner in browsing. Size of concepts and width of arcs indicate the collaboratively defined ranking, in decreasing order of significance.

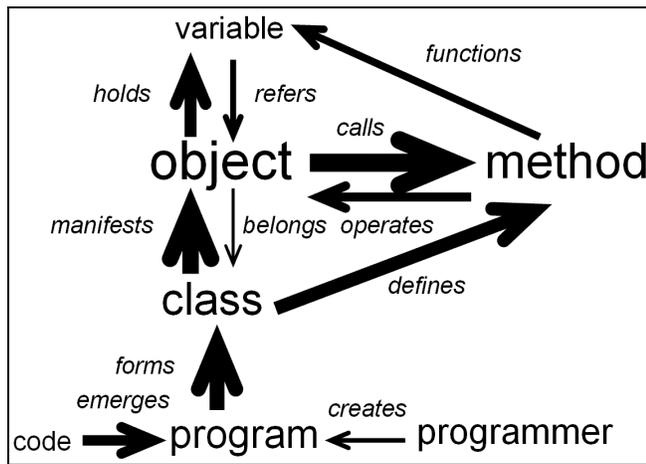


Figure 8.2 (originally published as Figure 1 in publication [P5]). Example of representation of concept maps and learning paths.

Learning activities offered by the method rely on two basic modes of browsing. In *topological view* the learner browses conceptual relationships in a certain concept map or between a group of related concept maps in a frozen time frame chosen by the learner, often the latest version. In *temporal view* the learner browses temporal versions of a concept map or a group of related concept maps in sequential time frames showing how the maps gradually evolve and get edited. These two views are generated by querying the database of concept map objects with edit histories. In addition, the method enables creating and editing user-defined learning paths based on certain parts of the conceptual relationship network in the concept map collection. A *learning path* for a desired learning topic primarily consists of a set of concepts and relationships considered pedagogically valuable to be explored to support the adoption of knowledge about the topic. The creation, editing and browsing of learning paths by the learners and educators is performed and recorded similarly as done with concept maps, supplied with recommendations about useful order and priority of exploring conceptual relationships supported by various sequential, branching and looping constellations.

As the learner browses the concept maps and learning paths from concept to concept about learning topic she aims to adopt, she becomes fruitfully exposed to various complementing perspectives. To enable diverse alternative perspectives the connectivity between concepts can be generated and adjusted based on various *relatedness criteria* concerning shared concepts and arcs, including high occurrence in concept maps or collaborative edit histories, popularity of being explored or included in learning paths, as well as quality of ratings or annotations given by the user community. In respect to collaborative edit history, a special priority is given to those occurrences supplied with a long duration and high frequency of contributions and involvement of learners with user profiles indicating high educational level and experience in current topic. The learner can freely adjust connectivity of concepts to display desired perspectives and the constantly updated view focuses to show local connectivity of concepts in respect to desired features of the conceptual network to be highlighted. To optimize cognitive load, the learner can adjust the number and type of concepts and arcs shown simultaneously and stay informed about already visited parts of concept maps.

To ensure and cumulatively enhance quality, each concept map and learning path submitted to the database is collaboratively evaluated by other learners assigning an overall *quality rating* on five-point Likert scale and more detailed ratings for each concept and relationship separately. Each concept map and learning path can be also annotated with comments concerning their reliability and usefulness. A learner can also publish a request to others about creating or editing concept maps or learning paths about a desired topic. To facilitate identifying related earlier submissions and then to explore or refine them, a search function enables learners to find most matching occurrences for a given set of key words, considering title, user profile, concepts, relationships, annotations and ratings.

We have carried out *empirical experiment* to evaluate educational gain of the proposed method. We report here corrected results that somewhat differ from those results reported in publication [P5], our analysis is based on material gathered from 147 university students of *introductory Java programming course* who we asked to draw with our method *concept maps* representing their knowledge about learning topic “programming”. Among these 147 students there were 124 men and 23 women and average of age of students was 20.86 years (median 20 years). Although we present here the results in English, the experiment was carried out in Finnish but we present the results here in English. User interface of a prototype tool used in the experiment is shown in Appendix M.

After eliminating unclear responses and transforming all concepts to non-conjugated base forms, and considering only those concepts and relationships mentioned by at least two students, we identified 167 unique concepts and 167 unique conceptual relationships between them. A full listing of these unique concepts and unique relationships supplied with occurrences in concept maps is shown in Appendix M. Five most frequent concepts, number of students who mentioned the concepts shown in parenthesis, were programming (90), object (62), method (60), java (57) and class (49). Five most frequent relationships, number of students who mentioned the relationships shown in parenthesis, were object → method (29), class → object (27), programming → programming language (27), programming language → java (18) and programming → language (17).

Table 8.1 shows how 147 students gradually introduced relationships to concept maps about programming. It appears that the most popular conceptual relationship that the students added as their first conceptual relationship to concept maps was programming → language (mentioned by 11 students). The most popular conceptual relationship to be added as their second conceptual relationship was programming → programming language (mentioned by 7 students). The most popular conceptual relationship to be added as their third conceptual relationship was object → method (mentioned by 6 students).

To analyze pedagogical value of the method we compared evolution of drawn concept maps to an extensive *narrative from 28 lectures* of introductory Java programming course (Sahami 2010). We computed that this lecture narrative contained 6291 unique concepts that had altogether 101599 occurrences. We compared drawn concept maps to co-occurring words in 18142 unique sentences of the lecture narrative.

The high-ranking concepts and high-ranking conceptual relationships in drawn concept maps well matched with the high-ranking concepts and highest-ranking co-occurring concept pairs in the pedagogical narrative. For example, ten *highest-ranking concepts* of concept maps and ten highest-ranking concepts of narrative had overlap of about 65 percent, and ten *highest-ranking relationships* of concept maps and ten highest-ranking co-occurring concept pairs of narrative had overlap of about 50 percent. Motivated by additional analysis, we introduce here corrected results about experimentally gathered data and thus results reported here somewhat differ from those results originally presented in publication [P5].

Table 8.1. Listings showing how 147 students gradually introduced conceptual relationships to concept maps that they drew about programming, these three listings show the most occurring relationships in first, second and third relationship each student has added (n=147). Only those relationships are shown that were mentioned by at least two students.

The most actively introduced conceptual relationships when the student added <u>the first</u> relationship to her concept map		The most actively introduced conceptual relationships when the student added <u>the second</u> relationship to her concept map		The most actively introduced conceptual relationships when the student added <u>the third</u> relationship to her concept map	
<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>	<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>	<i>Conceptual relationship</i>	<i>Number of students mentioning this relationship</i>
programming -> language	11	programming -> programming language	7	object -> method	6
class -> object	8	class -> object	6	language -> python	4
programming -> programming language	8	programming language -> java	5	programming language -> c	4
programming -> object	4	language -> java	4	class -> method	3
programming -> object-oriented programming	3	language -> c	3	class -> object	3
programming -> program	3	object -> method	3	language -> java	3
object -> method	2	variable -> object	3	programming language -> java	3
program -> class	2	class -> method	2	method -> object	2
programming -> java	2	code -> program	2	object -> list	2
programming -> python	2	java -> object	2	object -> variable	2
programming -> tool	2	object -> variable	2	programming -> c++	2
programming -> variable	2	package -> class	2	programming -> java	2
variable -> object	2	programmer -> programming	2	programming -> language	2
		programming -> logic	2	programming -> program	2
		programming -> object	2		

From Table 8.2 it can be seen that among ten highest-ranking concepts for lecture narrative concepts (when counting concepts thing and things as one) there seem to be six concepts specific for describing learning topic of programming including: class, program, method, object, value and array. On the other hand ten highest-ranking concepts for concept maps about programming, if we first exclude language-related vocabulary and concepts directly referring to concept of programming itself, include

five concepts: object, method, class, program and variable. Thus when comparing these two sets of concepts (six concepts and five concepts) four of them are shared (i.e. class, method, object and program) thus resulting in matching overlap of about 65 percent. We think that this result indicates that the proposed relatively self-guided method can assist learners to generate and process knowledge in a pedagogically rewarding way, even challenging the knowledge evolution process suggested by a professional teacher.

Table 8.2. Highest-ranking concepts in lecture narrative of introductory Java programming course (having at least 262 occurrences) available from Sahami (Sahami 2010) and concept maps about programming (having at least 8 occurrences) drawn by students (n=147). Conjugated forms of concepts of concept maps were transformed into base form but concepts of lecture narrative were kept in initial conjugated forms since reliable automated transformation seemed challenging and manual transformation laborious.

Highest-ranking concepts in lecture narrative of introductory Java programming course		Highest-ranking concepts in concept maps about programming	
<i>Concept</i>	<i>Occurrences</i>	<i>Concept</i>	<i>Occurrences</i>
thing	1007	programming	90
class	902	object	62
program	836	method	60
time	757	java	57
things	742	class	49
name	640	program	47
way	613	programming language	44
method	604	variable	41
object	585	python	31
value	558	c	29
array	511	programmer	25
string	485	language	24
sort	478	object-oriented programming	22
set	463	computer	21
number	435	user	21
stuff	395	compiler	20
people	387	C++	19
means	368	code	17
run	367	user interface	16
line	350	loop	13
call	349	debugger	12
use	343	eclipse	12
doing	342	problem	11
computer	342	algorithm	9
variable	338	conditional sentence	9
file	330	int	9
take	327	parameter	9
show	327	program code	9
java	325	ready program	9
point	313	starting method	9
code	291	tool	9
example	283	library	8
list	263	machine language	8
type	262	testing	8
world	258		
start	255		
bit	254		

When analyzing the *highest-ranking conceptual relationships* in concept maps about programming shown in Table 8.3 (based on Appendix M), and first excluding language-related vocabulary and concepts directly referring to concept of programming itself, we ended up observing those nine highest-ranking relationships marked with an asterisk (*) and one of those six relationships marked with a double asterisk (**) since these six relationships share the same ranking. In these ten relationships 5 concepts become mentioned anyway (object (6 occurrences), class (5 or 6 occurrences), method (3 or 4

occurrences), variable (3 or 4 occurrences), program (1 or 2 occurrences)) and additionally possibly one of three concepts become mentioned (code (0 or 1 occurrences), package (0 or 1 occurrences) and programmer (0 or 1 occurrences)).

Table 8.3. Comparison concerning conceptual relationships of concept maps about programming and co-occurring concepts of lecture narrative of introductory Java programming course available from Sahami (Sahami 2010). As explained in main text of Subchapter 8.2 in our further analysis we ended up observing those nine highest-ranking relationships marked with an asterisk (*) and one of those six relationships marked with a double asterisk (**) since these six relationships share the same ranking.

The highest-ranking conceptual relationships in concept maps about programming drawn by students (n=147) (only those relationships occurring at least 5 times shown here, more shown in Appendix M)		How many times each of 50 highest-ranking concepts of lecture narrative of introductory Java programming course co-occurs with any other word(s) of 50 highest-ranking concepts in a same phrase, and how many times each of these 50 concepts occurs irrespective of co-occurrences		
<i>Conceptual relationship</i>	<i>Occurrences</i>	<i>Conceptual relationship</i>	<i>Co-occurrences</i>	<i>Occurrences (ranking)</i>
* object->method	29	thing	344	1007 (1)
* class->object	27	things	240	742 (5)
programming->programming language	27	way	230	613 (7)
programming language->java	18	name	214	640 (6)
programming->language	17	sort	214	478 (13)
* class->method	14	method	203	604 (8)
java->object	14	time	198	757 (4)
programming->program	14	class	196	902 (2)
* object->variable	12	program	194	836 (3)
language->java	11	set	180	463 (14)
language->c	10	object	165	585 (9)
* program->class	10	show	165	327 (27.5s)
* object->class	9	means	161	368 (18)
* variable->object	9	call	160	349 (21)
java->object-oriented programming	8	doing	160	342 (23.5s)
language->python	8	value	158	558 (10)
programming language->c	8	array	155	511 (11)
programming->object	8	use	155	343 (22)
programming->object-oriented programming	8	run	144	367 (19)
programming language->python	7	stuff	130	395 (16)
* class->variable	6	number	127	435 (15)
* method->object	6	string	125	485 (12)
object-oriented programming->java	6	take	125	327 (27.5s)
programming->computer	6	inside	120	235 (43)
programming->java	6	people	118	387 (17)
programming->tool	6	bunch	115	222 (48)
c->C++	5	variable	111	338 (25)
** code->program	5	computer	107	342 (23.5s)
java->class	5	type	105	262 (34)
** method->class	5	bit	105	254 (37)
** method->variable	5	start	103	255 (36)
** package->class	5	code	94	291 (31)
** programmer->program	5	line	92	350 (20)
programmer->programming	5	java	92	325 (29)
programmer->programming language	5	list	81	263 (33)
programming->programmer	5	example	79	283 (32)
programming->user interface	5	text	79	219 (50)
programming->variable	5	point	77	313 (30)
** variable->method	5	size	72	229 (45.5s)
		file	69	330 (26)
		integer	66	232 (44)
		move	63	246 (38)
		case	63	241 (41s)
		zero	61	245 (39)
		world	58	258 (35)
		box	55	220 (49)
		album	52	226 (47)
		times	51	229 (45.5s)
		loop	46	241 (41s)
		screen	37	241 (41s)

From lecture narrative we identified how many times each of 50 highest-ranking concepts co-occurs with any other concept(s) of 50 highest-ranking concepts in a same phrase. The number of these co-occurrences is shown in Table 8.3 for each of 50 highest-ranking concepts. In this listing it can be seen that among ten highest-ranking concepts for lecture narrative concepts (when counting concepts thing and things as one) there seems to be six concepts specific for describing learning topic of programming including: sort, method, class, program, set and object. Thus when comparing these two sets of concepts (5 or 6 actively used concepts in relationships of concept maps about programming and 6 actively used concepts in phrase-based co-occurrences of lecture narrative) four of them are shared (i.e. class, method, object and program) thus resulting in matching overlap of about 65 percent.

We analyzed the drawn concept maps in respect to the *learner's self-evaluation* about three characteristics based on responses given by students after drawing concept map in experiment: amount of earlier programming experience, difficulty of learning programming and the complexity of the concept map she had drawn, measured with five-point Likert scale (response alternatives are listed in Appendix M). Based on this analysis Table 8.4 shows distribution of rankings of concepts of concept maps about programming in respect to responses given by students and Table 8.5 shows distribution of rankings of conceptual relationships of concept maps about programming in respect to responses given by students. Here we took into account only such concepts and conceptual relationships that were mentioned by at least two students. We observed surprisingly coherent concept maps to be drawn irrespective of the responses given in self-evaluation. For example, for ten highest-ranking concepts as well as conceptual relationships there was overlap of about 50 percent between more experienced and less experienced learners, between learners considering learning more difficult and learners considering it less difficult, and between learners who drew more complex concept maps and learners who drew less complex concept maps.

We think that these results indicate that our proposed method can assist learners to generate and process knowledge in such a way that lets even challenged learners to reach same knowledge qualities in their concept maps as the less-challenged learners can.

Table 8.4. Distribution of rankings of concepts of concept maps about programming in respect to responses given by students, for concepts mentioned by at least two students.

How much you have experience about programming before participating programming course? (It can be expected to be clear for the students from the context that this question refers specifically to their current introductory programming course.)					
Very little or little (n=80+39=119)		Moderately (n=20)		Very much or much (n=1+7=8)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	71	programming	14	java	5
object	57	compiler	7	programming	5
method	55	programming language	7	language	4
java	46	java	6	c	3
class	45	program	6	program	3
program	38	programmer	6	php	2
variable	36	method	5	programmer	2
programming language	35	object	5	programming language	2
python	28	object-oriented programming	5	python	2
c	23	variable	4		
Is it easy for you at the moment to learn programming?					
Very easy or easy (n=10+42=52)		Moderate (n=85)		Very difficult or difficult (n=1+9=10)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	30	programming	55	object	5
java	21	object	41	programming	5
method	16	method	40	method	4
object	16	class	35	program	4
program	16	java	34	class	3
programming language	16	program	27	user	3
c	12	programming language	26	variable	3
object-oriented programming	12	variable	26	algorithm	2
variable	12	python	21	c	2
class	11	c	15	code	2
programmer	11			computer	2
				int	2
				java	2
				language	2
				object-oriented programming	2
				programmer	2
				programming language	2
Please give an estimate about how complex things your concept map is dealing with?					
Very simple or simple (n=32+83=115)		Moderate (n=26)		Very complex or complex (n=4+2=6)	
Concept	Occurrences	Concept	Occurrences	Concept	Occurrences
programming	71	programming	15	programming	4
object	51	object	10	java	2
java	50	method	9	language	2
method	50	program	9	program	2
class	41	programming language	9	python	2
program	36	class	7		
programming language	35	programmer	7		
variable	34	variable	6		
python	26	compiler	5		
c	24	java	5		

Table 8.5. Distribution of rankings of conceptual relationships of concept maps about programming in respect to responses given by students, for conceptual relationships mentioned by at least two students.

How much you have experience about programming before participating introductory programming course? (It can be expected to be clear for the students from the context that this question refers specifically to their current introductory programming course.)					
Very little or little (n=80+39=119)		Moderately (n=20)		Very much or much (n=1+7=8)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
class->object	25	programming->programming language	5	language->java	3
object->method	24	object->method	5	programming->programming language	2
programming->programming language	20	programming->language	3	language->c	2
class->method	14	programming language->java	3	programming->language	2
java->object	14	(many, shown in footnote) ¹⁸	2	programming language->java	2
programming->program	13				
programming language->java	13				
programming->language	12				
object->variable	10				
language->c	8				
language->java	8				
variable->object	8				
program->class	8				
object->class	8				
Is it easy for you at the moment to learn programming?					
Very easy or easy (n=10+42=52)		Moderate (n=85)		Very difficult or difficult (n=1+9=10)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
programming->programming language	12	class->object	19	object->method	3
object->method	9	object->method	17	class->object	2
class->object	6	programming->programming language	15	programming->language	2
programming->program	5	programming language->java	13	object-oriented programming->java	2
language->java	5	java->object	12	programmer->code	2
programming language->java	5	programming->language	11	programming->object-oriented programming	2
java->object-oriented programming	4	class->method	10		
class->method	4	object->variable	9		
language->c	4	programming->program	8		
programming->language	4	program->class	7		
variable->object	4				
object->class	4				
programming->variable	4				
Please give an estimate about how complex things your concept map is dealing with?					
Very simple or simple (n=32+83=115)		Moderate (n=26)		Very complex or complex (n=4+2=6)	
Conceptual relationship	Occurrences	Conceptual relationship	Occurrences	Conceptual relationship	Occurrences
object->method	25	programming->programming language	6	programming->language	2
class->object	22	class->object	4		
programming->programming language	21	object->method	4		
programming language->java	16	object->variable	3		
programming->language	14	programmer->program	3		
java->object	13	programming language->object-oriented programming	3		
class->method	12	(many, shown in footnote) ¹⁹	2		
programming->program	11				
language->java	10				
object->variable	9				
language->c	9				

¹⁸ Two occurrences: class->method; class->variable; input->method; method->object; method->output; method->variable; package->class; program->bug; program->class; program->compiler; program->function; program->library; program->user; programmer->programming; programming->logic; programming->program; programming language->c; programming language->java; programming language->machine language.

¹⁹ Two occurrences: c->c++; class->object; class->variable; input->method; java->object-oriented programming; method->variable; method->output; object->variable; program->bug; program->class; program->compiler; program->function; program->library; programming language->c;

8.3. Findings and their relation to the entity of the dissertation

We do not know any previous similar proposal for a concept map based wiki. We aim to augment traditional wiki techniques for creating, editing and applying knowledge in learning based on a diverse database of collaborative contributions supplied with user profiles. Initial experiments indicate promising pedagogical value and various educational games can be incorporated based on browsing and editing concept maps which can be agglomerated to maturing entities and ontologies that get gradually refined and provide complementing alternative conceptualizations. We think that knowledge structures and user logs gathered with the method can be exploited in daily educational work for evaluating students' learning progress, modeling collaborative learning processes and identifying patterns of successful learning. The method could be easily augmented with components resembling those that have been developed for traditional wikis, data mining and clustering algorithms.

Publication [P5] presents a method for gathering individually created and edited concept maps as a collective resource for various educational purposes. This method can be seen as a repository for knowledge structures extending the idea of collaborative framework presented in publication [P1].

In a similar way, publication [P5] can be seen to extend the methods introduced in publications [P2], [P3] and [P4] to guide educational exploration.

The method of publication [P2] described how to explore great knowledge structures which rely on linked pieces of knowledge. Method of publication [P3] augments that by using various measures to highlight diverse alternative perspectives that are available for browsing in knowledge structures and method of publication [P4] exploits using these perspectives in parallel and with varied temporal versions to reach pedagogically meaningful coverage. The previous publications together offer a general approach for browsing wiki based knowledge entities that is described in the context of the hyperlink network of the Wikipedia. We found out that same kind of approach suits well to educational exploration with collaboratively built concept map collection as explained in publication [P5]. In addition, concept maps for the collection introduced in publication [P5] can be at least partly produced with the methods described in earlier publications concerning guidance for building concept maps. Already so far identified bidirectional supportive relatedness between methods introduced in previous publications and publication [P5] gives motivation for developing even further methodology for connecting linked pieces of knowledge and we thus decided to present a new method with publication [P6].

Chapter 9. Agglomerating pieces of knowledge built by community of learners with concept maps

In publication [P6] we proposed methodology for *agglomerating pieces of knowledge* created by a community of learners. We now here first explain basic idea and motivation about agglomerating pieces of knowledge built by a community of learners with *concept maps* and then we describe our way to apply and exploit this model in collaborative learning. Finally we describe our initial experimental results concerning using our new method for educational task. More details can be read from the original publication [P6]. We try to summarize here the main results and augment them with additional results that have been gathered after publication of the publication [P6].

The framework introduced in publication [P5] represented educational knowledge with collaboratively edited collection of concept maps and method of publication [P6] can be seen as an extension to recommend educationally fruitful routings to explore similar kind of conceptual network. Figure 9.1 illustrates the main idea of the method proposed in publication [P6].

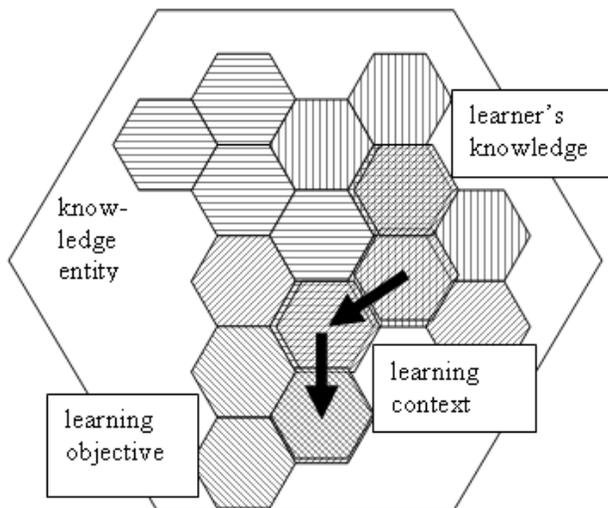


Figure 9.1. Main idea of the method proposed in publication [P6] for agglomerating pieces of knowledge built by community of learners with concept maps and how the learner can explore ranking-based routings connecting learning concept networks.

Similarly as in Figure 8.1, also in Figure 9.1 the linked hexagons together represented a collectively generated conceptual network. However now this network is not anymore a concept map collection as in publication [P5] but instead a collection of overlapping conceptual relationships representing the learner's knowledge, the learning objective and the learning context that are based on gathered text samples whose concepts are

linked based on corresponding hyperlinks of the Wikipedia. The method supports the learner to explore the shortest hyperlink chains leading from the learner's knowledge (represented with hexagons having vertical line pattern) to the learning objective (represented with hexagons having descending line pattern). The method recommends routes that can traverse either directly from the learner's knowledge to the learning objective or through intermediary parts based on contextual or collective conceptual network (each one represented with hexagons having unique line patterns), the latter case shown with two arrows in Figure 9.1.

9.1. Agglomerating knowledge in networks

The proposed method of publication [P6] aims to generate intuitive ways for connecting pieces of educational knowledge based on semantically motivated *routings in hyperlink network* of the Wikipedia.

Tetchueng et al. (2008) propose learning systems with generic context-aware scenarios to deal with problem-based learning based on a didactic model and community of practices. Lee and Kwon (Lee & Kwon 2008) suggest an expert system supporting collective decision making relying on fuzzy cognitive mapping with dynamic weighted graphs. Osmundson et al. (1999) showed that collaborative concept mapping helps learning scientific and principled information and reaching inter-connectivity between systems of the learning topic. Suthers et al. (2009) showed that collaborative problem solving based on concept mapping outperformed threaded discussions and suggested a protocol for studying asynchronous collaboration. Gurlitt and Renkl (2010) represented how different concept mapping tasks lead to a variety of cognitive processes, learning outcomes and perceived self-efficacy. Chujo (2004) measured vocabulary levels in educational texts with a high-frequency word list based on the British National Corpus and identified a diverse set of partially shared and constantly evolving vocabularies. Hilpert and Gries (2009) suggest methods for interpreting temporarily ordered stages of corpora and studying language acquisition. They argue that vocabularies and conceptual relations have different configurations for each individual, group, developmental stage and context.

Graph theoretical brain network analysis has gained promising attention and small-world topology has been observed in human brain networks under various structural and functional conditions (Wang et al. 2010). Goldstone et al. (2008) argue that in dissemination of innovations in a social network, small-world networks are beneficial when solving a difficult problem. Auber et al. (2003) suggest that relevant information on the network can be deduced from a hierarchical decomposition into small-world sub-networks and the hierarchy can be efficiently used to navigate the network. Zhao (2009) demonstrated a documentation process enabling to construct and visualize small-world network models and to establish the paths within the models by searching the related web pages. Zaidi et al. (2009) suggest a clustering method to identify hidden community structures and to facilitate browsing Web pages in scale-free small-world network.

Due to previous results and since the Wikipedia holds scale-free small-world properties ((Zesch & Gurevych 2007); (Masucci et al. 2011)), we think that the Wikipedia's hyperlink network can inherently provide relatively optimal structure for exploring educational knowledge.

9.2. Finding learning paths with learning concept networks

Relying on the knowledge structure of the Wikipedia, in publication [P6] we propose a new computational method to support personalized adoption of knowledge by creating the closest mappings between *learning concept networks*. We think that for any topic it is possible to define a variety of alternative learning concept networks each one addressing a specific perspective and being based on a unique collection of concepts, called as a *key vocabulary*, and specific relationships determined between these concepts.

Some important features for collective intelligence systems are possible individual user actions, system state, as well as community and individual objectives (Lykourantzou et al. 2009). Motivated by previous results, we suggest generating learning concept networks for three complementing perspectives: the learner's knowledge, the learning objective and the learning context. *Learner's knowledge* refers to a personally flavored entity of knowledge and perspective about a certain learning topic acquired by the learner. *Learning objective* refers to a compact yet thorough entity of widely agreed knowledge describing a learning topic. *Learning context* refers to a diverse collection of everyday knowledge and collectively shared perspectives surrounding a learning topic induced by the members of the learner's community.

Motivated by convincing learning results based on *high-frequency word lists* (Masterson et al. 2010), in our method key vocabularies are identified by selecting a set of concepts having the highest frequencies in a representative text sample. A text sample for learning objective is gained by retrieving a Wikipedia article whose title matches with the topic. A text sample for learner's knowledge is gained by asking the learner to write a short improvised essay explaining her current conceptualization about the topic or the learner may just provide a list of few essential key concepts describing the topic, or draw a simple concept map representing key concepts and their relationships. A text sample for learning context is gained by collecting an extensive set of essays (or lists of key concepts or concept maps) from various learners in which they collectively describe their cumulative conceptualization about a variety of everyday topics. In our method, each learning concept network is built by connecting concepts of the key vocabulary based on the shortest hyperlink chains between corresponding Wikipedia articles.

We have implemented the proposed method in a prototype relying on a relational MySQL database storing learning concept networks in compact text format and a Java application enabling to visually edit and browse concept maps based on Java Database Connectivity interface (JDBC API). We used *online database service "Six degrees of Wikipedia"* to make queries about the shortest hyperlink chains between any given two

concepts in the English edition of Wikipedia, based on article collection dating from 3 March 2008 (Dolan 2011).

When finishing this dissertation it seems that the online database service “Six degrees of Wikipedia” (Dolan 2011) may not anymore return to be functional as it used to be but it needs to be emphasized that our results gained with that online service were needed especially as a proof of concept in preliminary experiments of prototyping. Thus we expect that our results should remain their value irrespective of functioning of that online service (please note that we have mentioned this claim already in publication [P6]) and could be successfully replicated and applied with alternative similar methods if needed and in fact in Subchapters 12.2–12.4. we report about further experiments that we have carried out which aim to cover similar tasks of finding the shortest path between a pair of Wikipedia articles (based on article collection dating from June–July 2013) as was provided by online database service (Dolan 2011).

Since longer hyperlink chains tended to reveal some interesting indirect relatedness but also to introduce ambiguousness, we decided to consider only chains containing one hyperlink or two hyperlinks with a requirement that the intermediate concept also belongs to key vocabulary. Based on occurrence distribution in collection of all the shortest hyperlink chains, our method creates two rankings: *concept ranking* for concepts belonging to key vocabulary and *hyperlink ranking* for hyperlinks existing between pairs of concepts belonging to key vocabulary.

The method builds a learning concept network based on representative sets of concepts and hyperlinks that have reached the highest rankings and introduces a *three-level pedagogic hierarchy* to indicate pedagogic value of concepts and hyperlinks. The method first adds the highest-ranking concepts and better half of them belong to the first level while the others to the second level. Then the method adds the highest-ranking hyperlinks and better half of them belong to the first level while the rest to the second level. These hyperlinks can connect already existing concepts or alternatively additional concepts need to be added which belong to the third level. Finally, the method aims to connect still separate segments of the network into one entity by gradually adding new hyperlinks and possibly new concepts based on the remaining ranking list of hyperlinks. In this last phase both concepts and hyperlinks belong to the third level.

By comparison, the method tries to find shared vocabularies, i.e. concepts that are shared by each pair of learning concept networks, called as *learner–context vocabulary*, *context–objective vocabulary* and *learner–objective vocabulary*. They enable to define a minimal collection of the shortest hyperlink chains that connect all concepts belonging to a pair of learning concept networks, called as *learner–context routing*, *context–objective routing* and *learner–objective routing*. Learning concept networks are illustrated to the learner as personalized adaptive concept maps, called as *learner’s knowledge map*, *learning context map* and *learning objective map*. To avoid excessive cognitive load, these concept maps are typically shown to the learner only partially step by step along the learning scenario. Our proposed method aims to support learning basically with two complementing modes that can be also mixed together: assisted construction and assisted evaluation. In both modes, despite the actual direction of hyperlinked concepts each hyperlink can be traversed in both directions.

9.3. Implementing learning activities with learning concept networks

In *assisted construction mode*, the method recommends what hyperlinked concepts could be next added to learner's knowledge map to gradually approach concepts belonging to learning objective map. Two complementing approaches are available. In *focused approach*, the learner is recommended to traverse hyperlinks along learner-objective routing to reach concepts of learning objective map. In *contextualized approach*, the learner is first recommended to traverse hyperlinks along learner-context routing to reach learner-context vocabulary in learning context map. Next, the learner is recommended to traverse in learning context map the shortest hyperlink chains connecting learner-context vocabulary and context-objective vocabulary. Then the learner is recommended to traverse hyperlinks along context-objective routing to reach concepts of learning objective map. In both approaches, the learner is finally asked to traverse the shortest hyperlink chains connecting all concepts of learning objective map. Focused approach aims to emphasize the learner's personal perspective and specific conceptual details in acquisition of new knowledge whereas contextualized approach tries to emphasize collectively shared perspectives in her community and conceptual structures on a broader scale.

Based on the recommendations, the learner is expected to explore conceptual structures hyperlink by hyperlink and meanwhile to expand gradually the learner's knowledge map by adding new hyperlinked concepts to represent her knowledge acquisition process, resembling methods introduced in publications [P2]-[P4]. In each step, the method shows two updated ordered lists of the currently most recommended hyperlinks to traverse next for both focused and contextualized approach, sorted in decreasing order of significance. The orderings of the lists are generated to guide the learner to proceed in the parallel hyperlink chains of routings in an order similar to breadth-first graph search algorithm. Hyperlinks that diverge from routings are also recommended but with lower rankings. Beside the hyperlinked concept, each row in the list shows a condensed relation statement extracted from the text defining the hyperlink in corresponding Wikipedia article (verb and some adjacent words nearest to the hyperlink anchor in this article).

In *assisted evaluation mode*, the learner is provided with the learner's knowledge map but without recommendations based on routings concerning what hyperlinked concepts could be next added. Two alternative types of browsing can be used. In *targeted browsing*, the learner is provided with a list of all concepts belonging to learning objective map and she is asked to expand learner's knowledge map gradually until reaching these concepts. In *open browsing*, concepts belonging to learning objective map are not revealed to the learner and she is simply asked to expand learner's knowledge map gradually until she considers that it covers the most essential concepts in the learning topic. Targeted browsing aims to emphasize learning towards predefined goals whereas open browsing tries to emphasize learning with learner-driven goal-

setting. In both types of browsing, the learner is allowed to add only such a hyperlinked concept that there is a corresponding Wikipedia article directly hyperlinked from/to another Wikipedia article corresponding to a concept currently belonging to learner's knowledge map. The learner is asked to mark concepts that she considers to represent everyday knowledge or collectively shared perspectives with a label "contextualized" and concepts that she considers to represent more specific knowledge or personal perspectives with a label "focused".

When the learner has decided to finish, the method compares how much the gradually added hyperlinked concepts, both "contextualized" and "focused", correspond to exploring the routings based on the recommendations of the assisted construction mode with contextualized and focused approaches respectively. The amount of overlap between added hyperlinked concepts and the routings is used to measure the quality of the learner's learning efforts and is reported to the learner. Both in assisted construction mode and assisted evaluation mode, the learner is expected to encounter and become fruitfully exposed to conceptual structures that pedagogically relate her previous knowledge to new knowledge about the learning topic. If the learner is unfamiliar with a concept recommended by the method, she is provided with a definition by showing a Wikipedia article with a corresponding title. The process remains relatively self-guided in all steps and it typically ends when the learner self considers.

As already motivated in Subchapter 5.2, assisted construction mode can be considered to support learners representing cognitive style of *field dependence* and assisted evaluation mode to support learners representing cognitive style of *field independence*.

To evaluate the educational value of the proposed method we performed preliminary testing based on simple *learning scenarios* about children aiming to adopt basic vocabulary used in everyday life. The key vocabularies of learner's knowledge and learning objective consisted of the highest-ranking 10 percent of the nouns in text samples provided by the learner and the Wikipedia article respectively about selected topics. The key vocabulary of learning context consisted of 100 highest-ranking nouns used by English speaking children queried from Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) for combination of early educational levels denoted by "Rec/Prep/K" that we will refer to as school level Preparatory (<http://www.oxfordwordlist.com/pages/search.asp>). Appendix O shows the key vocabulary of learning context as well as one key vocabulary of learner's knowledge and one key vocabulary of learning objective in one of the learning scenarios concerning learning topic "child".

Based on three key vocabularies shown in Appendix O, Figure 9.2 (originally published as Figure 1 in publication [P6]) illustrates learning context map (a), learning objective map (b) and learner's knowledge map (c) in one of the learning scenarios concerning learning topic "child". Arc labels (i.e. relation statements) were omitted from the figure to preserve clarity. To indicate three-level pedagogic hierarchy for concepts, the first level has bold font, the second level normal font, the third level italics font and concepts added in the final connecting phase an asterisk (*). To indicate three-level pedagogic hierarchy for hyperlinks, the first level has bold arcs, the second level

normal arcs and the third level dotted arcs. In the shown case, learner-objective vocabulary and learner-objective routing turn out to be empty and thus the focused approach cannot be used but contextualized approach is still applicable. Learner-context vocabulary contains concepts Father, Game, School and Sibling, and context-objective vocabulary a concept Time. Between these concepts the shortest hyperlink chains in learning context map rely on the following hyperlink chains: Father ← Family → Sibling, Family ← Party → School, Family ← House ← Toy ↔ Game, Toy → Food → School, Party ← Holiday ↔ Day ↔ Time and Game ↔ Play(activity) ← Play(disambiguation) ← Party.

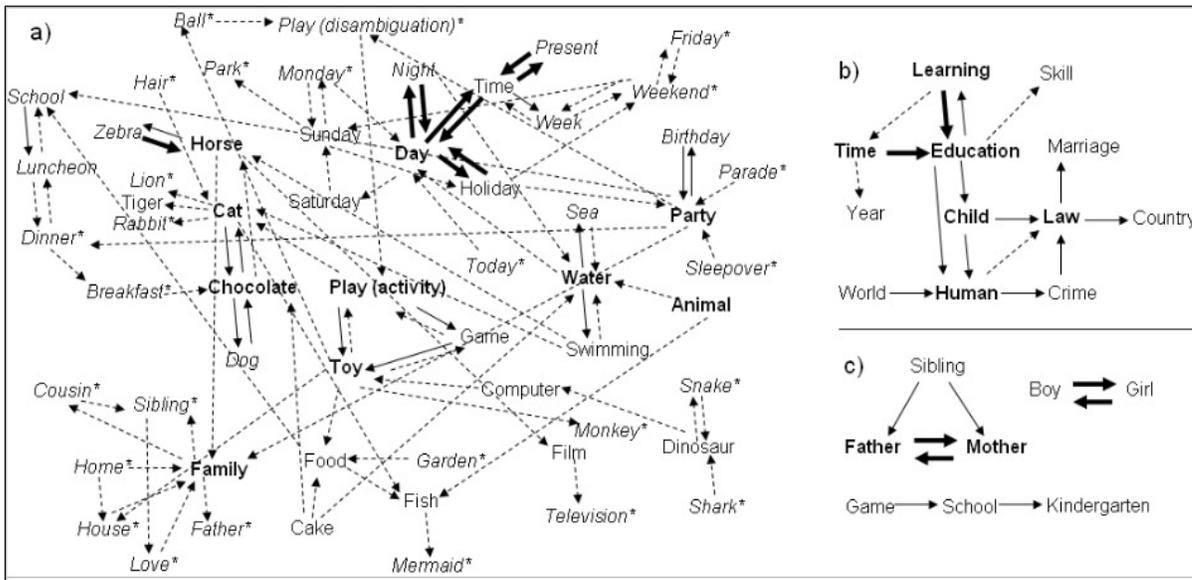


Figure 9.2. (originally published as Figure 1 in publication [P6]). Learning context map (a), learning objective map (b) and learner's knowledge map (c).

Figure 9.3 (originally published as Figure 2 in publication [P6]) shows in user interface how the learner, currently at concept Family, explores conceptual structures leading from learner's knowledge map to learning objective map, following hyperlink by hyperlink the recommendations given by the method. Please note that preferred traversing direction may go against the actual direction of hyperlink. In the shown case the learner is using contextualized approach. Just before arriving to current status the learner might have traversed hyperlinks Sibling ← Family and Father ← Family (written here in preferred traversing direction against the actual direction of hyperlinks and thus the learner would have in practice traversed from concept Sibling to concept Family and from concept Father to concept Family). The method shows sequentially lists of the currently most recommended hyperlinks to traverse next. In contextualized approach while currently at concept Family the learner can now select for example to traverse next hyperlink Family ← Party (in practice traversing from concept Family to concept Party). Therefore a chain of traversed hyperlinks leading from learner's knowledge map to learning objective map might include for example following hyperlinks (written here in preferred traversing direction that may go against the actual direction of hyperlinks): Sibling ← Family, Father ← Family, Family ← Party, Party ←

Holiday, Holiday ↔ Day and Day ↔ Time. The learner is also recommended to explore hyperlinks that diverge from routings and which cross-link concepts of vocabularies. We think that even this small sample gives convincing emphasis on some essential conceptual structures about learning topic “child” and indicates educationally valuable resource for adoption of new concepts and overall conceptualization of the learner.

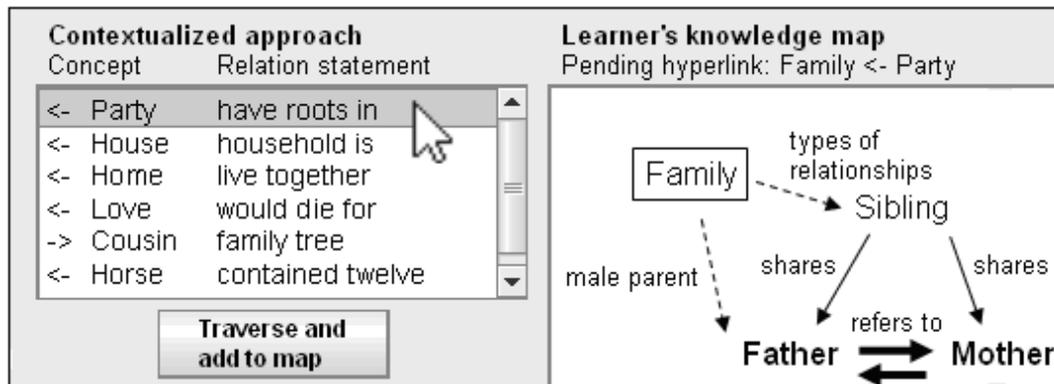


Figure 9.3. (originally published as Figure 2 in publication [P6]). User interface (an excerpt) of the prototype in assisted construction mode.

To verify the suggested pedagogic value of knowledge acquisition with the proposed method we gathered an extensive *collection of concept maps* drawn by 103 students describing their flow of association covering diverse pedagogic topics and containing 1827 conceptual relationships and compared them to corresponding *automated exploration patterns* in learning concept networks containing 1601 conceptual relationships generated with the proposed method. Here we mean with automated exploration pattern that the student is supplied with a computer-assisted navigation system that automatically retrieves and visualizes available hyperlinks to be traversed next from current concept but however student is expected to actively select the next hyperlink to traverse from provided set of alternative hyperlinks. Therefore we compared *traversed hyperlinks* in exploration paths in “hyperlink network of 55 concepts” (n=49) which we consider automated exploration patterns with *conceptual relationships in concept maps* drawn by students (n=103) which we consider non-automated exploration patterns. In this current analysis, the set of conceptual relationships in concept maps drawn by students is based on same sample that we introduced in Subchapter 3.9 (it is explained in Subchapter 3.9 how we gathered this sample).

In statistical comparison, we found positive correlation among the highest-ranking conceptual relationships between automated and non-automated exploration patterns in various topics with overlap ranging up to 60–70 percent, thus indicating that automated method can fruitfully guide the learner’s exploration along paths that are intuitively preferred in non-automated learning. With resembling positive results, we found convincing overlap even when comparing automated exploration patterns of younger learners to non-automated exploration patterns of older learners thus indicating that the method can enhance maturing of learning process. Similarly, the method seemed to enhance how individual conceptual relationships agglomerated and concept maps

matured along the exploration. It thus seems that the method can support learning with recommendations based on traversing hyperlink chains to form the closest mappings between all concepts of the learning concept networks.

Table 9.1 enables comparison of the highest-ranking core relationships²⁰ in concept maps drawn by students and the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (case of traversed hyperlinks was explained originally in publication [P9]). Full listing is shown in Appendix N. Table 9.2 enables comparison of rankings of the highest-ranking core relationships of concept maps and the highest-ranking traversed hyperlinks that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N).

In contrast with practice used often elsewhere in this publication, in Table 9.1, Table 9.2 and Appendix N if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is a ranking value that would have been used next if there was not need for sharing the position (i.e. we now avoid using an average of all ranking values that would have been used if there was not need for sharing the position and skipping corresponding number of ranking values). We decided to use all ranking values even in case of shared ranking so that our analysis about overlap of listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks could become more intuitive in the following text.

Figure 9.4 (explained originally in publication [P9]) enables comparison of rankings of *highest-ranking core relationships of concept maps drawn by students* (34 relationships) and *highest-ranking traversed hyperlinks* in exploration paths of students (51 hyperlinks of which 17 are unidirectional and 34 have a hyperlink going also into opposite direction) that are shared by both listing of core relationships of concept maps and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N).

Based on Table 9.2 we compared listing of highest-ranking core relationships in concept maps drawn by the students (in column 1) and listing of highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (in column 4), this analysis was assisted by a third listing showing traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks (in column 8).

²⁰ Please note that a specific meaning for term “core relationship” has been defined in Subchapter 3.10.

Table 9.1. Comparison of the highest-ranking core relationships in concept maps drawn by students (n=103) and the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), based on listings of Table 3.9 and Appendix K (full listing is show in Appendix N). Those relationships that exist in both listings are indicated with an asterisk (*). This table is limited to shown only those core relationships having at least 6 occurrences and those traversed hyperlinks having at least 13 occurrences, for full listing see Appendix N. The number of traversals for hyperlinks departing from Human (i.e. value 19) includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis (i.e. value 2) is shown the number of traversals when excluding those traversed hyperlinks departing from concept Human that were the student's first traversed hyperlink in exploration path.

<i>Concept maps drawn by the students (n=103)</i>			<i>Exploration paths in the Wikipedia (n=49)</i>		
<i>Core relationships (i.e. relationships between 102 core concepts extended with concept "brother" that are mentioned by at least two students in concept maps drawn by students) shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, thus each pair of concepts are shown in alphabetical order) (n=103)</i>	<i>Occurrences (at most one occurrence counted for each student)</i>	<i>Ranking</i>	<i>Traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>	<i>Occurrences (at most one occurrence counted for each student)</i>	<i>Ranking</i>
Family=Friendship	15	1	Happiness->Emotion	29	1
* Birth=Death	13	2s	* Emotion->Love	26	2
* Family=Love	13	2s	Joy->Happiness	24	3s
Friendship=School	10	3	* Disease->Death	24	3s
* Family=Home	9	4s	Happiness->Joy	21	4
School=Work	9	4s	Human->Diet (nutrition)	19 (2)	5s
* Animal=Nature	8	5s	Emotion->Experience	19	5s
* Friendship=Love	8	5s	Experience->Emotion (only to roll back)	18	6
* Child=Family	7	6s	Organism->Biology	17	7s
Death=Living	7	6s	Adolescence->Education	17	7s
* Family=Father	7	6s	* Love->Friendship	16	8
Family=Living	7	6s	Education->Learning	14	9s
Joy=Sorrow	7	6s	Learning->Education	14	9s
* Family=Mother	6	7s	Emotion->Happiness	14	9s
* Father=Mother	6	7s	* Family->Mother	13	10s
Food=Water	6	7s	Diet (nutrition)->Health	13	10s
Friendship=Hobby	6	7s	* Health->Disease	13	10s
Money=Work	6	7s			

When considering traversed hyperlinks that have a ranking position as high as possible in both listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks based on their average (in column 8) it turned out that four hyperlinks with this kind of highest average ranking positions (Love → Friendship, Disease → Death, Family → Mother and Love → Family) covered four ranking levels of seven first ranking levels for core relationships (based on ranking levels shown in column 3) and four ranking levels of eight first ranking levels for traversed hyperlinks (based on ranking levels shown in column 6). Thus with this sample we concluded that there was an overlap of core relationships and traversed hyperlinks in the range 50–57 percent ($4/8=0.50$ and $4/7\approx 0.57$).

Table 9.2 part 1 of 3 (starts here and continues on next page). Comparison of rankings of the highest-ranking core relationships of concept maps and the highest-ranking traversed hyperlinks that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). To enable comparison of core relationships and traversed hyperlinks each concept of core relationship is transformed to the closest matching entry of Wikipedia article. Based on Table 9.1 and Appendix N (Appendix N shows full listing) this table shows only those core relationships of concept maps drawn by students and traversed hyperlinks of the Wikipedia in exploration paths of students that are shared by both listing of core relationships and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). In core relationships concepts are shown so that they are transformed to the closest matching entry of Wikipedia article. In columns 2 and 3 ranking values for core relationships are shown both among all core relationships and among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students. In columns 5 and 6 ranking values for traversed hyperlinks are shown both among all traversed hyperlinks and among only those traversed hyperlinks that are shared with core relationships. In column 7 ranking values are shown also for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing). In addition, column 9 shows a listing of traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks. This listing of column 9 aims to suggest a ranking of such relationships and hyperlinks that appear among the highest-ranking positions in both listing of core relationships and traversed hyperlinks, relying on average of ranking values for current hyperlink and corresponding relationship (from columns 3 and 6). Please note that listing of core relationships is shorter than listing of traversed hyperlinks.

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
Birth=Death	2s	1s	Emotion->Love	2	12s	1	Love->Friendship	3
Family=Love	2s	1s	Disease->Death	3	14s	2	Disease->Death	4.5s
Family=Home	4	2	Love->Friendship	8	20s	3	Family->Mother	4.5s
Animal=Nature	5s	3s	Family->Mother	10s	21s	4s	Love->Family	4.5s
Friendship=Love	5s	3s	Health->Disease	10s		4s	Emotion->Love	5
Child=Family	6s	4s	Love->Happiness	11	18s	5	Animal->Nature	6.5s
Family=Father	6s	4s	Friendship->Adolescence	12s	not existing	6s	Health->Disease	6.5s
Family=Mother	7s	5s	Love->Emotion	12s	2	6s	Love->Happiness	6.5s
Father=Mother	7s	5s	Biology->Nature	13s	not existing	7s	Child->Family	7s
Nature=Plant	8s	6s	Human->Family	13s	not existing	7s	Family->Child	7s
Plant=Tree	8s	6s	Oxygen->Water	13s	19s	7s	Human->Family	7s
Death=Disease	9s	7s	Death->Disease	14s	3	8s	Biology->Nature	7.5s
Family=Human	9s	7s	Death->War	14s	not existing	8s	Death->Disease	7.5s
Human=Love	9s	7s	Love->Family	14s	not existing	8s	Friendship->Adolescence	7.5s
Human=Nature	9s	7s	Family->Sibling	15s	20s	9s	Love->Emotion	7.5s

Table 9.2 part 2 of 3 (started on previous page and continues here).

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
Animal=Human	10s	8s	Plant->Tree	15s	not existing	9s	Nature->Animal	7.5s
Biology=Nature	10s	8s	Sea->Water	15s	15s	9s	Plant->Tree	7.5s
Death=Human	10s	8s	Water->Sea	15s	15s	9s	Birth->Death	8s
Death=Old_age	10s	8s	Animal->Human	16s	21s	10s	Death->War	8s
Death=War	10s	8s	Animal->Nature	16s	18s	10s	Family->Father	8s
Education=School	10s	8s	Child->Family	16s	16s	10s	Home->Family	8s
Food=Health	10s	8s	Death->Human	16s	not existing	10s	Oxygen->Water	8s
Happiness=Love	10s	8s	Education->School	16s	16s	10s	Plant->Nature	8s
Home=House	10s	8s	Family->Child	16s	16s	10s	Father->Family	8.5s
Nature=Sun	10s	8s	Mother->Love	16s	not existing	10s	Friendship->Love	8.5s
Adolescence=Friendship	11s	9s	Plant->Nature	16s	19s	10s	Animal->Human	9s
Disease=Health	11s	9s	School->Education	16s	16s	10s	Death->Human	9s
Emotion=Love	11s	9s	Teacher->School	17	18s	11	Education->School	9s
Family=Sibling	11s	9s	Family->Father	18s	19s	12s	Family->Sibling	9s
Leisure=Television	11s	9s	Happiness->Love	18s	11	12s	School->Education	9s
Love=Mother	11s	9s	Nature->Animal	18s	16s	12s	Sea->Water	9s
Oxygen=Water	11s	9s	Nature->Human	18s	not existing	12s	Water->Sea	9s
School=Teacher	11s	9s	School->Teacher	18s	17	12s	Father->Mother	9.5s
Sea=Water	11s	9s	Father->Family	19s	18s	13s	Mother->Father	9.5s
			Human->Love	19s	not existing	13s	Mother->Love	9.5s

Table 9.2 part 3 of 3 (started two pages earlier and continues here).

<i>Highest-ranking core relationships in concept maps drawn by the students (n=103)</i>			<i>Highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>				<i>Traversed hyperlinks of the Wikipedia in exploration paths of students in decreasing order of average of ranking values based on core relationships and traversed hyperlinks</i>	
Core relationships shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order)	Ranking among all core relationships	Ranking among only those core relationships that are shared with traversed hyperlinks of the Wikipedia in exploration paths of students	Traversed hyperlinks	Ranking among all traversed hyperlinks	Ranking for a traversed hyperlink going into opposite direction than current traversed hyperlink (if existing)	Ranking among only those traversed hyperlinks that are shared with core relationships (so that each concept is transformed to the closest matching entry of Wikipedia article)	Traversed hyperlinks	Average of ranking values for current hyperlink and corresponding relationship (from third and sixth column)
			Nature->Plant	19s	16s	13s	Nature->Human	9.5s
			Nature->Sun	19s	not existing	13s	Nature->Plant	9.5s
			Old_age->Death	19s	not existing	13s	Happiness->Love	10s
			Water->Oxygen	19s	13s	13s	Human->Love	10s
			Father->Mother	20s	20s	14s	Mother->Family	10s
			Friendship->Love	20s	8	14s	Teacher->School	10s
			Home->Family	20s	not existing	14s	Nature->Sun	10.5s
			House->Home	20s	not existing	14s	Old_age->Death	10.5s
			Mother->Father	20s	20s	14s	School->Teacher	10.5s
			Sibling->Family	20s	15s	14s	House->Home	11s
			Birth->Death	21s	not existing	15s	Water->Oxygen	11s
			Health->Food	21s	not existing	15s	Health->Food	11.5s
			Human->Animal	21s	16s	15s	Human->Animal	11.5s
			Leisure->Television	21s	21s	15s	Sibling->Family	11.5s
			Mother->Family	21s	10s	15s	Leisure->Television	12s
			Television->Leisure (only to roll back)	21s	21s	15s	Television->Leisure (only to roll back)	12s

Similarly when considering eight hyperlinks with this kind of highest average ranking positions in column 8 (Love → Friendship, Disease → Death, Family → Mother, Love → Family, Emotion → Love, Animal → Nature, Health → Disease, Love → Happiness) these eight hyperlinks covered eight ranking levels of nine first ranking levels for core relationships (based on ranking levels shown in column 3) and eight ranking levels of ten first ranking levels for traversed hyperlinks (based on ranking levels shown in column 6). Thus with this sample we concluded that there was an overlap of core relationships and traversed hyperlinks in the range 80–89 percent ($8/10=0.80$ and $8/9\approx 0.89$).

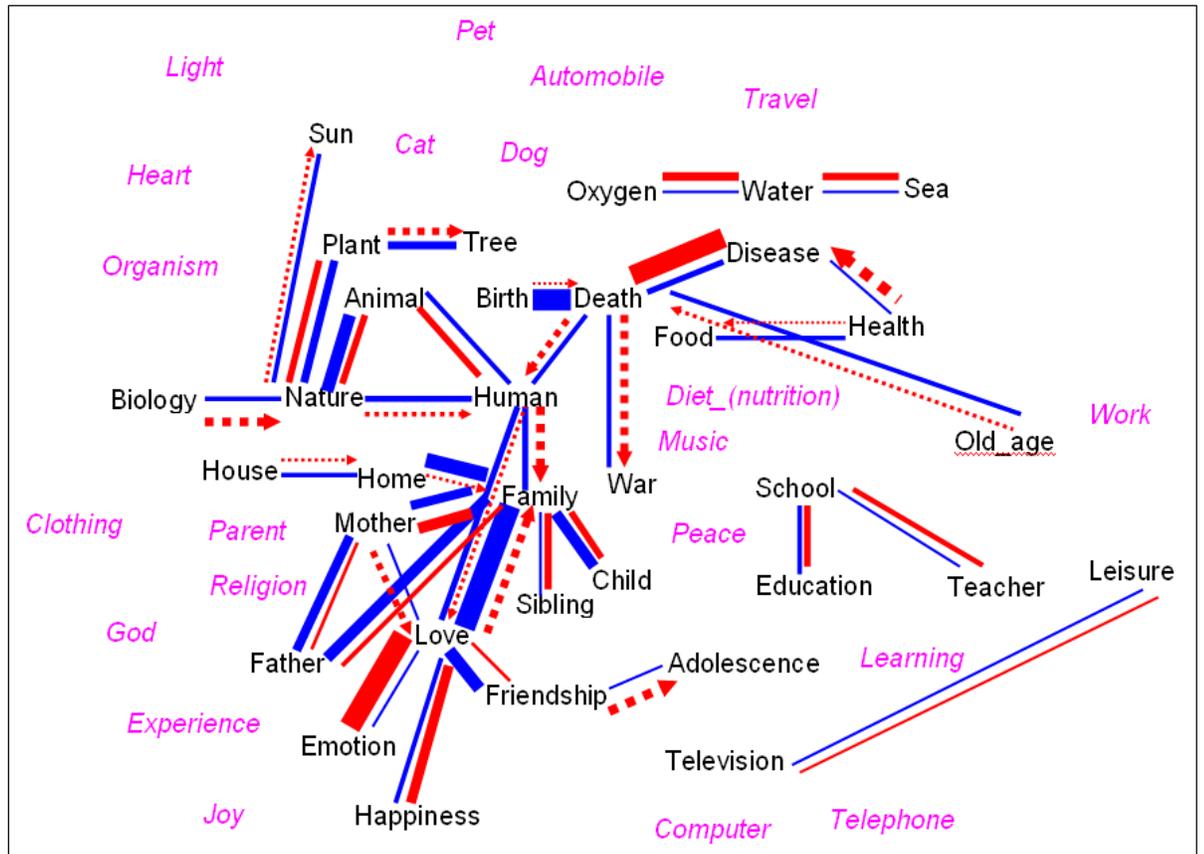


Figure 9.4 (originally published as Figure 2b in publication [P9]). Based on Table 9.2 this figure shows only those core relationships of concept maps drawn by students ($n=103$) and traversed hyperlinks of the Wikipedia in exploration paths of students ($n=49$) that are shared by both listing of core relationships of concept maps and listing of traversed hyperlinks (thus showing here all those relationships and hyperlinks indicated with an asterisk (*) in Appendix N). Figure contains all 55 concepts that were available for exploration paths of students and concepts written in pink color do not belong to those core relationships of concept maps and traversed hyperlinks that are shared by both listings (each concept is transformed to the closest matching entry of Wikipedia article). Core relationships of concept maps are shown with blue lines and traversed hyperlinks with red lines. Greater width of line indicates higher position in ranking among those core relationships of concept maps and traversed hyperlinks that are shared by both listings, and the range of line widths is normalized for both listings to enable direct comparability. If there is a traversed hyperlink in both directions between two concepts the connection is supplied with a solid line and the higher one of two available line widths is shown. If there is a traversed hyperlink in only in one direction between two concepts the connection is supplied with a dotted line that indicates direction with an arrow.

9.4. Findings and their relation to the entity of the dissertation

Consensus is missing for a general learning theory and many pedagogic theories are hard to implement computationally. Despite theoretic advances, there is a lack of educational tools letting the learner to construct interactively her learning path in the light of expressive sequential model, relying on for example strategic planning, game theory or stochastic network models. To address this, we suggest one possible generalizable method to support various personalized and contextualized learning tasks and pedagogic games, currently offering guidance for complementing learning modes of

assisted construction and assisted evaluation with two variants. The method also enables finding shared understanding with peers or teacher. Our method can be seen as an effort to agglomerate and synthesize parallel emerging ontologies that represent complementing perspectives of educational knowledge. We do not know any similar previous proposal.

The method of publication [P6] has been designed to address the challenge of finding the shortest path to connect pieces of educational knowledge. The method extends the ideas of previous publications. Publication [P1] defined a framework for collaborative building of concept maps representing shared knowledge structure. To extend that method, in publication [P6] we propose method allowing to identify the shortest paths to traverse in shared knowledge structure. Publication [P2] proposed a method recommending paths for exploration in the hyperlink network of the Wikipedia and thus can be seen to establish the underlying general principles to generate knowledge structures that are used in publication [P6]. Publication [P3] proposed using Wikipedia article statistics to find alternative exploration paths addressing various perspectives for browsing in Wikipedia and publication [P4] proposed exploring various parallel paths and using temporal versions to cover educationally fruitful knowledge. Extending those ideas of offering recommendation for pedagogically meaningful exploration in knowledge structures, the method of publication [P6] aims to find ways to connect individually created pieces of knowledge represented with concept maps. The publication [P5] presented idea of collective gathering of knowledge in form of concept maps and this collective approach can be augmented with the method of the publication [P6] to identify and exploit linking between pieces of knowledge.

PART V. Forming new educational activities based on vocabularies, conceptual networks and spaced learning

Chapter 10. Potential of learning based on conceptual networks

In publications [P1]-[P6], discussed in Chapters 4-9, we have proposed methods based on educational processes in which the learner explores and builds linked knowledge structures. We now here provide detailed analysis about experiments that we have carried out with students to verify suggested benefits of our proposed method to support educational exploration in conceptual network based on hyperlink network of the Wikipedia. First in Subchapter 10.1 we make a brief review about results of previous research concerning measuring the effect of a certain educational practice (i.e. pedagogical gain for using a certain learning method). Then in Subchapter 10.2 we describe and analyze results of our experiment concerning recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network after exploration task. Finally in Subchapter 10.3 we describe and analyze results of our experiment concerning recall of shown hyperlinks forming the shortest paths in hyperlink network after exploration task.

10.1. Effectiveness of new learning methods

In educational research the effect that an intervention, for example a new more inspiring teaching method, has on learning achievements of students has been often measured with effect size. *Effect size* is often defined as a difference between the mean outcome for the intervention group and mean outcome for the control group, divided by pooled sample standard deviation. Alternatively, the effect size is a difference between the mean outcome in the end of intervention and mean outcome in the beginning of intervention, divided by pooled sample standard deviation. These are said to be two major formulas for calculating effect sizes (Hattie 2009). With this kind of definitions, the effect size is a measure expressing how many standard deviations fit between the mean of intervention group and the mean of control group, or correspondingly between the mean in the end of intervention and the mean in the beginning of intervention. Standard deviations are often different when measured on student level, class level, school level or national level making comparisons challenging. Bloom et al. (2008) mention that a *national standard deviation* is generally larger than standard deviation for study samples and that *student-level standard deviations* are typically several times the size of *school-level standard deviations* and furthermore that most studies use student-level standard deviations.

Effect size of 1.0 can be seen to indicate increase of one standard deviation on improving school achievement, corresponding to advancing student's achievement by 2–3 years, improving the learning rate by 50 percent or having a correlation of 0.50 between intervention method and achievement (Hattie 2009). Bloom et al. (2008) mention based on earlier research a widely cited benchmark that an intervention should have an effect size of 0.25 to be *educationally significant* (Tallmadge 1977) and that from 186 meta-analysis covering 6700 studies of educational, psychological and behavioral interventions it was found that bottom third of the distribution of effect sizes ranged between 0.00–0.32 standard deviation, middle third between 0.33–0.55 standard deviation and top third between 0.56–1.20 standard deviation (Lipsey 1990).

Based on 815 meta-analyses, covering 52637 educational studies with millions of students and 146142 effect sizes, Hattie (Hattie 2009) found that 95 percent of effect sizes were above zero, thus seeming to explain why almost any action has at least a mild positive effect on achievement, and that the *average of effect sizes* was 0.40 which he suggests to be used as a benchmark between effects that need more consideration and effects that are worth having. Hattie claims, motivated by his own New Zealand studies and results of Johnson and Zwick (Johnson & Zwick 1990), that teachers can accomplish on average an effect size of 0.20–0.40 on the student's school achievement per year. He considers effects sizes in range 0–0.15 to correspond developmental effects that can be achieved even without schooling, effect sizes in range 0.15–0.40 to correspond effects from a teacher in a typical year of schooling and effect sizes above 0.40 to correspond effects of influences that can be expected to have the greatest impact on the student achievement outcomes.

According to review of experiments comparing effectiveness of human tutoring, computer tutoring and no tutoring Vanlehn (Vanlehn 2011) concluded that when compared to the case of no tutoring, human tutoring has effect size of 0.79 and intelligent tutoring system has an effect size of 0.76.

According to Hattie's synthesis of 815 meta-analyses (Hattie 2009), *six main categories of influences* (contributors) to learning and their average effect sizes, in parenthesis, are: teacher (0.49), curricula (0.45), teaching (0.42), student (0.40), home (0.31), and school (0.23). Hattie identified 138 different influences to learning belonging to these six categories and Table 10.1 shows forty influences having the highest-ranking effect sizes among these 138 influences in descending order of effect size. Table 10.2 shows all those influences to learning that belonging to category of "teaching" and have effect size of at least 0.40 according to Hattie. Just below threshold 0.40 are teaching influences concerning time on task (0.38), computer-assisted instruction (0.37) and adjunct aids (0.37).

When extending previous synthesis to cover 931 meta-analyses Hattie (Hattie 2012) found that the overall ranking of influences to learning based on effect size changed relatively little. Now six main categories of influences to learning and their average effect sizes are: teacher (0.47), curricula (0.45), teaching (0.43), student (0.39), home (0.31), and school (0.23). In respect to forty highest-ranking effect sizes shown in Table 10.1, now four old influences dropped out, including home environment (0.52), socio-economic status (0.52), professional development (0.51) and goals (0.50), and four new

influences entered, including response to intervention (1.07), teacher credibility (0.90), classroom discussion (0.80) and student-centered teaching (0.54). In respect to teaching influences having effect size of at least 0.40 shown in Table 10.2, now two old influences dropped out, including social skills programs (0.39) and matching style of learning (0.17).

Table 10.1. Forty influences to learning that have the highest-ranking effect sizes according to Hattie’s meta-analysis (Hattie 2009) concerning 138 influences, each influence shown with rank, category and effect size in descending order of rank.

Rank	Category	Influence	Effect size
1	student	self-report grades	1.44
2	student	Piagetian programs	1.28
3	teaching	providing formative evaluation	0.90
4	teacher	micro teaching	0.88
5	school	acceleration	0.88
6	school	classroom behavioral	0.80
7	teaching	comprehensive interventions for learning disabled students	0.77
8	teacher	teacher clarity	0.75
9	teaching	reciprocal teaching	0.74
10	teaching	feedback	0.73
11	teacher	teacher-student relationships	0.72
12	teaching	spaced vs. mass practice	0.71
13	teaching	meta-cognitive strategies	0.69
14	student	prior achievement	0.67
15	curricula	vocabulary programs	0.67
16	curricula	repeated reading programs	0.67
17	curricula	creativity programs	0.65
18	teaching	self-verbalization/self-questioning	0.64
19	teacher	professional development	0.62
20	teaching	problem-solving teaching	0.61
21	teacher	not labeling students	0.61
22	curricula	phonics instruction	0.60
23	teaching	teaching strategies	0.60
24	teaching	cooperative vs. individualistic learning	0.59
25	teaching	study skills	0.59
26	teaching	direct instruction	0.59
27	curricula	tactile stimulation programs	0.58
28	curricula	comprehension programs	0.58
29	teaching	mastery learning	0.58
30	teaching	worked examples	0.57
31	home	home environment	0.57
32	home	socioeconomic status	0.57
33	teaching	concept mapping	0.57
34	teaching	goals	0.56
35	curricula	visual-perception programs	0.55
36	teaching	peer tutoring	0.55
37	teaching	cooperative vs. competitive learning	0.54
38	student	pre-term birth weight	0.54
39	school	classroom cohesion	0.53
40	teaching	Keller’s Personalized System of Instruction	0.53

Based on meta-analysis covering more than 100 studies, Marzano et al. (2001) listed *nine categories of instructional strategies* that have a strong influence on student achievement and gave estimates for the average effect size of each of these strategies:

identifying similarities and differences (1.61), summarizing and note taking (1.00), reinforcing effort and providing recognition (0.80), homework and practice (0.77), nonlinguistic representations (0.75), cooperative learning (0.73), setting objectives and providing feedback (0.61), generating and testing hypotheses (0.61), and questions, cues and advance organizers (0.59).

Table 10.2. All those influences to learning that belong to category of teaching and have effect size of at least 0.40 according to Hattie's meta-analysis (Hattie 2009), shown in descending order of effect size and with value of ranking among all 138 influences.

Rank	Category	Influence	Effect size
3	teaching	providing formative evaluation	0.90
7	teaching	comprehensive interventions for learning disabled students	0.77
9	teaching	reciprocal teaching	0.74
10	teaching	feedback	0.73
12	teaching	spaced vs. mass practice	0.71
13	teaching	meta-cognitive strategies	0.69
18	teaching	self-verbalization/self-questioning	0.64
20	teaching	problem-solving teaching	0.61
23	teaching	teaching strategies	0.60
24	teaching	cooperative vs. individualistic learning	0.59
25	teaching	study skills	0.59
26	teaching	direct instruction	0.59
29	teaching	mastery learning	0.58
30	teaching	worked examples	0.57
33	teaching	concept mapping	0.57
34	teaching	goals	0.56
36	teaching	peer tutoring	0.55
37	teaching	cooperative vs. competitive learning	0.54
40	teaching	Keller's Personalized System of Instruction	0.53
44	teaching	interactive video methods	0.52
53	teaching	questioning	0.46
61	teaching	behavioral organizers / adjunct questions	0.41
62	teaching	matching style of learning	0.41
63	teaching	cooperative learning	0.41

In teaching word meanings, Eeds and Cockrum (Eeds & Cockrum 1985) compared three instructional methods based on teaching words by helping students to expand an existing conceptual network, having students to pair new words with dictionary definitions and having students to read words in a meaningful context of junior novel, and they found that the first method was significantly more effective than the other two methods. When compared with a traditional learning method with listing and studying definitions, Carr and Mazur-Stewart (Carr & Mazur-Stewart 1988) managed to significantly improve the vocabulary comprehension and retention of terms with a method relying on a graphic organizer to relate text information, personal clues to associate terms with background knowledge and self-monitoring checklist to assess understanding.

10.2. Recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network after exploration task

We have experimentally gathered data covering the educational processes when the learner explores and builds linked knowledge structures. We provide now results of our experiment concerning *recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network after exploration task*.

As already motivated in Subchapter 5.2, experimental setup for recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network discussed here in Subchapter 10.2 can be considered to support learners representing cognitive style of *field independence* whereas experimental setup for recall of shown hyperlinks forming the shortest paths in hyperlink network discussed in Subchapter 10.3 can be considered to support learners representing cognitive style of *field dependence*.

To reliably make comparative evaluation, we have carried out observation in conceptual network corresponding to a small but specifically selected subset of the hyperlink network of Wikipedia. With this subset we hope to have enough overlap to cover activities of various learners and to successfully compare the structural characteristics emerging in the conceptualization of both the individual learner and mutual agreement about well-defined basic knowledge done by collective community building the Wikipedia. We empirically observed how learners proceed and form conceptual chaining in the conceptual network of “hyperlink network of 55 concepts” (characteristics of “hyperlink network of 55 concepts” are described in Subchapter 5.3).

We have carried out with 73 students having ages in range of 16–20 years an experiment that enables to analyze the *process of exploration tasks* in hyperlink network of the Wikipedia and to give verification to *suggested educational benefits* gained with these exploration tasks. This exploration experiment and its preliminary results have been discussed in publication [P7] but based on further analysis after publishing publication [P7] we now present here partially different, corrected results. We compared two learning cases by asking an experiment group (n=49) and a control group (n=24) to perform an exploration task. Please note that the members of the experiment group and control group consist of completely different people than the group of 103 students which was explained in Subchapter 3.9 (i.e. there is no overlap of persons for these three experimental groups: group of 103 students explained in Subchapter 3.9, experiment group and control group). Although we present here the results in English, the exploration task was carried out in Finnish based on Finnish translations of all 212 hyperlinks shown in Appendix J supplied with a relation statement for each hyperlink.

Each member of the *experiment group* (n=49) was allowed to browse freely following their intuition in the conceptual network for twenty steps. This exploration task was carried in “hyperlink network of 55 concepts” starting from concept Human (all 212 hyperlinks of “hyperlink network of 55 concepts” supplied with their relation statements are listed in Appendix J). Starting from concept Human was motivated by our earlier finding that among 69 shared concepts in hyperlink network of the

Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5. At each step a few alternative hyperlinked concepts to be traversed next were shown to the student and the student actively selected which of these hyperlinked concepts to traverse next. Each of hyperlinked concepts were highlighted and accompanied with sentence related to corresponding hyperlink and each of these hyperlinks could be traversed only once (thus each traversed hyperlink disappears from being shown if exploration would later arrive back to start concept of traversed hyperlink). The student was given an instruction to read carefully all sentences in given list and to select with mouse the sentence whose highlighted word (i.e. hyperlinked concept) is most naturally connected to current concept shown above the list. Table 5.10 illustrates how during exploration task the student performs consecutive steps of exploration in “hyperlink network of 55 concepts”, a full listing of hyperlinks is shown in Appendix J.

In contrast with experiment group, each member of the *control group* (n=24) on the other hand had to proceed a predefined fixed series of twenty text pages, each one of them providing same kind of sentences with highlighted hyperlinked concepts as for the experiment group but without continuity between these pages and without possibility to select a hyperlink to proceed next while keeping continuity between pieces of knowledge (the predefined fixed series of twenty text pages the students had to proceed is listed in Appendix W). Each of twenty pages represented a concept so that all hyperlinked concepts on this page corresponded to hyperlinks going from concept represented by this page to all those hyperlinked concepts and thus all hyperlinked concepts on the same page had a shared start concept. However when proceeding to next page the concept represented by the next page was not any of those hyperlinked concepts of previous page and thus continuity between consecutive pages was minimized on purpose. This series of twenty pages was created based on exploration paths we traversed before the experiment and then reorganizing the order of pages. During the experiment the student was given an instruction to read carefully all sentences and highlighted words (i.e. hyperlinked concepts) in a given list and then to press button Next with mouse to get a next list to be read.

After performing exploration task, both members of experiment group and members of control group were asked to recall and write all the highlighted hyperlinked concepts that had been shown to them during exploration task and duration of two minutes was given for this recall task. It needs to be noted that the participants were informed about the recalling task only after the exploration task had been already performed.

To identify how the suggested benefits of proposed method to support learning is related to characteristics of the students we asked after exploration task and subsequent recall task each student to report her gender and age and with four responses to estimate usefulness of the method when compared to traditional learning from a book, her interest in using the method for learning, how easy it is for her to adopt knowledge through reading and how successfully she performs at school (see Table 10.3, Table 10.4 and Table 10.5). The four last mentioned questions were replied by selecting a most suitable answer from a scale of five given alternatives. When reporting the results we have grouped some small statistical response groups with an aim to offer a better

overall representation about the distribution of responses. Full listing of background characteristics of members of experiment group and control group as well as user interfaces of prototype tools used in experiment are shown in Appendix W.

Our aim was to form experiment group and control group so that they share approximately same background characteristics but it appears in Table 10.4 and Table 10.5 that in control group the distributions of adoption ability and school performance are possibly positioned at a bit lower level than in experiment group. In addition it should be noted that these estimates about adoption ability and school performance are self-reported by students and thus for example self-critical students may have underestimated their skills. Furthermore our aim was to enable such exploration tasks that are as matching as possible for experiment group and control group but since both groups participated our experiment at the same time it was not possible to get exactly matching exposure of concepts and thus we try to eliminate unnecessary bias in following analysis so that we consider only part of conceptual exposure of control group.

Table 10.3. The number, age and gender distribution of students in experiment group and control group.

Value	Experiment group (n=49)			Control group (n=24) (* = one unrealistic age of a male student was ignored as explained in Appendix X)		
	Male and female	Male	Female	Male and female	Male	Female
Number of students	49 (100 %)	18 (37 %)	31 (63 %)	24 (100 %)	12 (50 %)	12 (50 %)
Average of ages (years)	17.39	17.33	17.42	17.52*	17.45*	17.58
Variance of ages	0.74	0.71	0.78	1.35*	1.27*	1.54

Table 10.4. Responses to question “How easy it is for you to adopt new knowledge through reading?”

Opinion	Experiment group (n=49)				Control group (n=24)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Very easy	6 %	3	1	2	4 %	1	1	0
Easy	43 %	21	7	14	25 %	6	2	4
Moderate	37 %	18	7	11	63 %	15	8	7
Difficult	10 %	5	3	2	8 %	2	1	1
Very difficult	4 %	2	0	2	0 %	0	0	0

Table 10.5. Responses to question “In your opinion, how successfully do you perform at school?”

Opinion	Experiment group (n=49)				Control group (n=24)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Excellently	10 %	5	3	2	4 %	1	0	1
Well	37 %	18	1	17	38 %	9	4	5
Satisfactorily	45 %	22	13	9	58 %	14	8	6
Fairly	8 %	4	1	3	0 %	0	0	0
Faintly	0 %	0	0	0	0 %	0	0	0

When observing exploration tasks we give emphasis on shown concepts and selected concepts. In following analysis with term *shown concepts* we refer to each of those highlighted hyperlinked concepts that become shown to the student during exploration task even if the student does not actively select to traverse to this hyperlinked concept (i.e. not necessarily actively selected but shown highlighted hyperlinked concepts), and with term *selected concepts* we refer to each of those highlighted hyperlinked concepts that the student actively selects to traverse during

exploration task. Some bias can originate to analysis since some hyperlinked concepts (in highlighted form) occur also in a non-hyperlinked form (in non-highlighted form) in sentences shown during exploration task and we decided that these non-hyperlinked occurrences are not included when counting the number of shown hyperlinked concepts in our analysis to simplify experimental setup.

During exploration task of experiment group (n=49) on average 34.16 unique hyperlinked concepts were shown to each student and after the experiment student could recall on average 11.33 unique hyperlinked concepts (about 33.2 percent) of them, and on average 13.80 unique hyperlinked concepts were selected by each student and after the experiment student could recall on average 8.94 unique hyperlinked concepts (about 64.8 percent) of them (explained originally in publication [P9] pyöristysvirhe33,1 jäänyt p9ään). When considering repeated exposure of some hyperlinked concepts for experiment group on average 101.51 hyperlinked concepts were shown to each student meaning on average 2.97 occurrences of each unique hyperlinked concept. Appendix Y lists for each member of experiment group hyperlinked concepts actively selected by student during exploration task and recalled hyperlinked concepts after exploration task in respect to shown hyperlinked concepts and selected hyperlinked concepts.

During exploration task of control group (n=24) originally 42 unique hyperlinked concepts were shown to each student and when considering repeated exposure of some hyperlinked concepts for control group originally on average 148 hyperlinked concepts were shown to each student meaning originally on average 3.52 occurrences of each unique hyperlinked concept. To make conceptual exposure of experiment group and control group more matching to enable more reliable comparison about the process of exploration tasks and suggested educational benefits gained with these exploration tasks we decided in following analysis to consider for control group only conceptual exposure concerning 34 most occurring unique hyperlinked concepts in exploration tasks of control group (when excluding eight hyperlinked concepts there were hyperlinked concepts having shared number of occurrences and here excluded hyperlinked concepts were selected in decreasing alphabetic order)²¹. Thus following analysis relies on such observation that during exploration task of control group (24 persons) 34 unique hyperlinked concepts were shown to each student and after the experiment student could recall on average 11.21 unique hyperlinked concepts (about 33.0 percent) of them. When considering repeated exposure of some hyperlinked concepts for control group on average 137 hyperlinked concepts were shown to each student meaning on average 4.03

²¹ When we decided in the following analysis to consider for control group only conceptual exposure concerning 34 most occurring unique hyperlinked concepts in exploration tasks of control group the original set of 42 unique hyperlinked concepts with occurrences in parenthesis were: Biology (10), Oxygen (9), Human (8), Organism (8), Adolescence (7), Family (7), Leisure (6), Sibling (6), Animal (5), Child (5), Plant (5), Diet_(nutrition) (4), Old_age (4), Sun (4), War (4), Water (4), Disease (3), Emotion (3), Happiness (3), Heart (3), Religion (3), Clothing (2), Education (2), Father (2), God (2), Health (2), House (2), Learning (2), Light (2), Love (2), Mother (2), Music (2), Parent (2), School (2), Sea (2), Teacher (2), Tree (2), Automobile (1), Death (1), Friendship (1), Nature (1) and Travel (1). In the following analysis to consider for control group only conceptual exposure concerning 34 unique hyperlinked concepts we excluded these eight hyperlinked concepts: Sea, Teacher, Tree, Automobile, Death, Friendship, Nature and Travel (for hyperlinked concepts having shared number of occurrences (two occurrences) we excluded hyperlinked concepts in decreasing alphabetic order).

occurrences of each unique hyperlinked concept. Appendix Y lists for each member of control group recalled hyperlinked concepts after exploration task in respect to original set of 42 shown unique hyperlinked concepts and final limited set of 34 shown unique hyperlinked concepts.

We estimated the effect size in favor of *shown hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student was exposed to in experimental group and control group divided by square root of pooled variance (see Table 10.6). For the effect size in favor of experiment group in contrast with control group we got an estimate value of about 0.02 which indicates such effects that based on previous research of Hattie (Hattie 2009) while belonging to effect size range of 0–0.15 correspond to developmental effects that can be achieved even without schooling. Although this limited difference in effects of experiment group and control group seems at first to indicate no specific reason to contrast learning methods of experiment group and control group we think that this limited difference indeed enables us to verify that the learning methods of both experiment group and control group have about shared recall rate in respect to many hyperlinked concept that are shown relatively passively to the student during reading.

We next estimated the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in experiment group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student actively selects to traverse in experiment group and the hyperlinked concepts shown to her during her traversal of exploration path in experiment group divided by square root of pooled variance (see Table 10.7). For the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in experiment group we got an estimate value of about 1.38 which indicates such effects that based on previous research of Hattie (Hattie 2009) while belonging to effect size values above 0.40 correspond to effects of influences that can be expected to have the greatest impact on the student achievement outcomes. In addition, gained effect size 1.38 is much higher than the average effect sizes of six main categories of influences (contributors) to learning according to Hattie’s synthesis of 815 meta-analyses that are in range 0.23–0.49 (Hattie 2009) or according to Hattie’s synthesis of 931 meta-analyses in range 0.23–0.47 (Hattie 2012) as we have just mentioned above.

When comparing our gained effect size of 1.38 to the highest-ranking influences among 138 different influences to learning Hattie has identified in 2009 (Hattie 2009), shown in Table 10.1, and similarly in 2012 (Hattie 2012), it appears that our effect size is only slightly behind the highest-ranking effect size belonging to influence of “self-report grades” in category of “student” having effect size of 1.44 and our effect size is above the second highest-ranking effect size belonging to influence of “Piagetian programs” in category of “student” having effect size of 1.28. In addition our gained effect of 1.38 is much higher than the highest-ranking effect size for influences

belonging to category “teaching” that is “providing formative evaluation” having effect size of 0.90 (see Table 10.2).

We want to emphasize that the effect sizes that we have estimated in our experiment do not aim to represent a comparison that contrasts exploration tasks with traditional learning activities happening in a school classroom and thus the effect sizes do not directly represent how much better learning achievement could be expected to be gained with our proposed methods when compared to traditional style of learning at school. Instead, our effect sizes try to contrast learning achievements of active learning process and passive learning process in adoption of knowledge, and with our proposed method the activity is supported by enabling the student to select the hyperlinked concepts to traverse thus adjusting direction of her traversal of exploration path and in the passive alternative that we use for comparison relies on just showing hyperlinked concepts without influence coming from any selection by the student.

We still estimated the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* by computing the difference of averages of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts the student selects to traverse in experiment group and the hyperlinked concepts shown to her during her traversal of exploration path in control group divided by square root of pooled variance (see Table 10.8). For the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group we got an estimate value of about 1.38 which indicates same kind of effects that we just discussed about concerning the effect size of 1.38 in favor of selected concepts in experiment group in contrast with shown concepts in experiment group. When comparing more precise value for effect sizes it turns out that the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in control group* 1.378442 is a bit lower than the effect size in favor of *selected hyperlinked concepts in experiment group* in contrast with *shown hyperlinked concepts in experiment group* 1.382165. Since the value of 1.378442 is a bit lower than the value of 1.382165 we suggest that the effects can be considered to be with a similar relative difference greater for the case of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group than for the case of selected concepts in experiment group in contrast with shown concepts in experiment group.

However, since self-reported background information about the students shown in Table 10.4 and Table 10.5 indicated that in control group the distributions of adoption ability and school performance are possibly positioned at a bit lower level than in experiment group these imbalanced characteristics may have contributed to the result that the effect size in favor of selected hyperlinked concepts in experiment group in contrast with shown hyperlinked concepts in control group gains greater values than the effect size in favor of selected concepts in experiment group in contrast with shown concepts in experiment group.

Table 10.6. Estimation of effect size when comparing experiment group with control group.

	Experiment group (n=49)	Control group (n=24)		
Unique hyperlinked concepts shown to the student	34.16327	34	Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student in experimental group and control group	0.011891
Unique recalled hyperlinked concepts	11.32653	11.20833		
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student	0.331541	0.329657	Effect size in favor of unique shown hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in control group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student in experimental group and control group divided by square root of pooled variance)	0.017281
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts shown to the student	0.01333	0.009401		

Table 10.7. Estimation of effect size when comparing selected hyperlinked concepts in experiment group with shown hyperlinked concepts in experiment group.

	Unique hyperlinked concepts actively selected by the student in experiment group (n=49)	Unique hyperlinked concepts shown to the student in <i>experiment group</i> (n=49)		
Unique hyperlinked concepts	13.79592	34.16327	Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>experiment group</i>	0.052399
Unique recalled hyperlinked concepts	8.938776	11.32653		
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.647929	0.331541	Effect size in favor of unique selected hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in experiment group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>experiment group</i> divided by square root of pooled variance)	1.382165
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.041465	0.01333		

Table 10.8. Estimation of effect size when comparing selected hyperlinked concepts in experiment group with shown hyperlinked concepts in control group.

	Unique hyperlinked concepts actively selected by the student in experiment group (n=49)	Unique hyperlinked concepts shown to the student in <i>control group</i> (n=24)		
Unique hyperlinked concepts	13.79592	34	Pooled variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>control group</i>	0.053311
Unique recalled hyperlinked concepts	8.938776	11.20833		
Proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.647929	0.329657	Effect size in favor of unique selected hyperlinked concepts in experiment group in contrast with unique shown hyperlinked concepts in control group (difference of proportions of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts actively selected by the student in <i>experiment group</i> and the unique hyperlinked concepts shown to the student in <i>control group</i> divided by square root of pooled variance)	1.378442
Variance of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts	0.041465	0.009401		

We think that this gives promising support for a claim that learning by browsing conceptual network with our method based on learner-driven exploration can support adopting and thus remembering and learning knowledge with an advantage that is equal or even better than a learning process consisting of being exposed to learning content in a more traditional way like by browsing lecture notes or lecture slides (corresponding to the more monotonic proceeding in knowledge by the control group). Even a further comparison provided extended support for achieving educational gain with our method. With experiment group it appeared that for those concepts that the members had personally actively selected to be traversed in the hyperlink network the recall rate was 65.1 percent, thus it is much more than the percentage of control groups recall rate for all concepts that they were exposed to.

After publishing publication [P7] we have carried out further analysis which has led us to suggest some relatively small changes to the values that we have presented in publication [P7] concerning our results of exploration task. For example, in publication [P7] we reported that the experiment group managed to reproduce about 65 percent of adopted concepts whereas the control group reproduced only about 28 percent, and our further analysis seems to indicate that indeed when concerning hyperlinked concepts that the student selects to traverse during traversal of exploration path the average of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts still should remain as about 65 percent for experiment group but for control group it should be about 33 percent instead of 28 percent. In addition, when concerning hyperlinked concepts that are shown to the student during her traversal of exploration path, it appeared that for both experiment group and control group the average of proportion of unique recalled hyperlinked concepts in respect to unique hyperlinked concepts is near value 33 percent.

We asked the background information after the exploration task so that the student should not be provided with any specific expectations about how to perform in exploration task but on the other hand it is possible that the very recent feeling that the student has just achieved about her personal performance in exploration task can unintentionally affect her aim to estimate for example her general ability to adopt knowledge through reading (i.e. she was asked to estimate her adoption ability in general case, not only in this case of exploration task). Anyway it is possible that since we asked each student to estimate her ability to adopt new knowledge through reading and her success in performing at school this self-reporting may have provided relatively subjective results and it would be useful to carry out additional verifying experiments so that analysis based on these two background characteristics could rely on measuring these two characteristics with more objective and diverse methods than just self-reporting.

We think that it is possible that a more passive type of exploration task offered to control group in contrast with experiment group may have introduced temporarily a bit additional pessimistic feelings to the students of control group that have lead them to give such estimates about adoption ability and school performance that have made response distributions positioned at a bit more towards negative responses than corresponding response distributions of experiment group. We think that it is possible

that the effect size in favor of experiment group in contrast with control group can be at least partially induced by the small difference in distributions concerning the student's own estimate about her ability to adopt knowledge through reading (thus in Table 10.4 response distribution of experiment group seems to be positioned at a bit more towards positive responses than corresponding response distributions of control group).

To get more insight about learning process we think that it is important to compare *information that is shown to the learner, information that is encountered (actively selected) by learner and information that is recalled by learner*. To address this we have generated Table 10.9 that enables comparison of 55 concepts of “hyperlink network of 55 concepts” between number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) concepts during exploration (based on Table 5.18). In addition, Appendix Z enables comparison of 55 concepts of “hyperlink network of 55 concepts” between number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique recalled concepts in respect to hyperlinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration. Furthermore, Table 5.18 shows for 55 concepts of “hyperlink network of 55 concepts” the number of revisits to concepts in exploration paths when for each concept at most one revisit can be counted for each student.

Table 10.9. Comparison of 55 concepts of “hyperlink network of 55 concepts” between number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) concepts during exploration.

Number of times hyperlinked concepts are shown to student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique encountered (actively selected) concepts in exploration path of 20 steps when each concept counted at most once for each student in <i>experiment group</i> (n=49) (based on Table 5.18)		
<i>Concept</i>	<i>Number of times shown for all students</i>	<i>Average number of times shown per each student</i>	<i>Concept</i>	<i>Number of unique recalled selected concepts by all students</i>	<i>Average number of unique recalled selected concepts per each student</i>	<i>Concept</i>	<i>Number of unique encountered (actively selected) concepts by all students</i>	<i>Average number of unique encountered (actively selected) concepts per each student</i>
Human	263	5.367346939	Emotion	24	0.489795918	Love	30	0.612244898
Family	243	4.959183673	Love	24	0.489795918	Emotion	28	0.571428571
Biology	234	4.775510204	Happiness	22	0.448979592	Human	28	0.571428571
Oxygen	222	4.530612245	Human	18	0.367346939	Experience	26	0.530612245
Happiness	199	4.06122449	Organism	18	0.367346939	Happiness	26	0.530612245
Love	198	4.040816327	Biology	17	0.346938776	Adolescence	25	0.510204082
Emotion	185	3.775510204	Family	17	0.346938776	Biology	23	0.469387755
Organism	180	3.673469388	Joy	16	0.326530612	Family	23	0.469387755
Animal	179	3.653061224	Education	15	0.306122449	Education	22	0.448979592
Religion	173	3.530612245	Adolescence	14	0.285714286	Death	21	0.428571429
Plant	161	3.285714286	Animal	13	0.265306122	Organism	21	0.428571429
Adolescence	156	3.183673469	Death	13	0.265306122	Diet (nutrition)	20	0.408163265
Sibling	153	3.12244898	Mother	13	0.265306122	Disease	20	0.408163265
Old_age	128	2.612244898	Oxygen	12	0.244897959	Health	19	0.387755102
Health	127	2.591836735	Disease	11	0.224489796	Joy	19	0.387755102
Child	125	2.551020408	Water	11	0.224489796	Animal	17	0.346938776
Diet (nutrition)	123	2.510204082	Father	10	0.204081633	Parent	17	0.346938776
War	121	2.469387755	Plant	10	0.204081633	Plant	17	0.346938776
Leisure	113	2.306122449	War	10	0.204081633	Child	16	0.326530612
Joy	93	1.897959184	Health	9	0.183673469	Friendship	16	0.326530612
Education	92	1.87755102	School	9	0.183673469	Nature	16	0.326530612
Disease	91	1.857142857	Sibling	9	0.183673469	Oxygen	16	0.326530612
God	90	1.836734694	Friendship	8	0.163265306	Heart	15	0.306122449
Sun	86	1.755102041	Sun	8	0.163265306	Learning	15	0.306122449
Father	84	1.714285714	Teacher	8	0.163265306	Mother	15	0.306122449
Heart	83	1.693877551	Child	7	0.142857143	War	13	0.265306122
House	82	1.673469388	Heart	7	0.142857143	Sibling	12	0.244897959
Water	82	1.673469388	Learning	7	0.142857143	Father	11	0.224489796
Clothing	80	1.632653061	Nature	7	0.142857143	Sun	11	0.224489796
Music	80	1.632653061	Peace	7	0.142857143	Water	11	0.224489796
Nature	80	1.632653061	Religion	7	0.142857143	Leisure	10	0.204081633
Mother	74	1.510204082	Tree	7	0.142857143	Religion	10	0.204081633
Death	62	1.265306122	Leisure	6	0.12244898	School	9	0.183673469
Parent	55	1.12244898	Parent	6	0.12244898	Teacher	9	0.183673469
School	53	1.081632653	God	5	0.102040816	Peace	8	0.163265306
Teacher	52	1.06122449	Diet (nutrition)	4	0.081632653	Sea	7	0.142857143
Television	52	1.06122449	Old_age	4	0.081632653	Television	7	0.142857143
Experience	49	1	Sea	4	0.081632653	Tree	7	0.142857143
Friendship	47	0.959183673	Experience	3	0.06122449	Light	6	0.12244898
Learning	44	0.897959184	Travel	3	0.06122449	Birth	5	0.102040816
Light	29	0.591836735	Work	3	0.06122449	God	5	0.102040816
Tree	28	0.571428571	Automobile	2	0.040816327	Old_age	5	0.102040816
Food	23	0.469387755	Birth	2	0.040816327	Work	5	0.102040816
Automobile	21	0.428571429	Home	2	0.040816327	Clothing	3	0.06122449
Travel	21	0.428571429	House	2	0.040816327	Travel	3	0.06122449
Birth	17	0.346938776	Clothing	1	0.020408163	Automobile	2	0.040816327
Sea	14	0.285714286	Light	1	0.020408163	Home	2	0.040816327
Peace	13	0.265306122	Music	1	0.020408163	House	2	0.040816327
Work	11	0.224489796	Television	1	0.020408163	Food	1	0.020408163
Home	2	0.040816327	Cat	0	0	Music	1	0.020408163
Computer	1	0.020408163	Computer	0	0	Cat	0	0
Cat	0	0	Dog	0	0	Computer	0	0
Dog	0	0	Food	0	0	Dog	0	0
Pet	0	0	Pet	0	0	Pet	0	0
Telephone	0	0	Telephone	0	0	Telephone	0	0

Based on Table 10.9 we can make some coarse estimates about dependencies that can influence adoption of new knowledge when a learner traverses hyperlinks in a conceptual network. Since during exploration task each member of experiment group (49 persons) traversed an exploration path containing 20 steps and thus on average 34.16 unique concepts were shown to each student and after the experiment the student could recall on average 11.33 unique concepts (about 33.2 percent) we can take from Table 10.9 into further analysis three sets of *eleven highest-ranking concepts* in respect to three properties that are *shown hyperlinked concepts*, *recalled selected hyperlinked concepts* and *encountered (actively selected) hyperlinked concepts*.

Therefore in decreasing order eleven highest-ranking concepts based on the number of times hyperlinked concepts are shown to student during her traversal of exploration path include Human, Family, Biology, Oxygen, Happiness, Love, Emotion, Organism, Animal, Religion and Plant. Similarly in decreasing order eleven highest-ranking concepts based on the number of unique recalled concepts in respect to hyperlinked concepts that are actively selected by the student during her traversal of exploration path include Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal (at the eleventh ranking position there were three concepts having shared number of recalled concepts including Animal, Death and Mother, each having 13 occurrences, but to enable comparison of three equally sized sets of eleven concepts we decided to select here only one of them in ascending alphabetic order and thus in the following analysis only Animal is considered to represent the eleventh ranking position). Also similarly in decreasing order based on the number of unique encountered (actively selected) hyperlinked concepts in exploration path when each concept counted at most once for each student include Love, Emotion, Human, Experience, Happiness, Adolescence, Biology, Family, Education, Death and Organism.

All these three high-ranking vocabulary sets share seven concepts of eleven concepts (about 64 percent) including Emotion, Love, Happiness, Human, Organism, Biology and Family, and additionally set of recalled selected concepts and set of encountered (actively selected) concepts share two concepts including Education and Adolescence, and set of recalled selected concepts and set of shown concepts share one concept including Animal. To coarsely estimate distance of revisiting a certain concept in exploration path for each of just mentioned shared seven concepts of eleven concepts it turned out that with paths having two occurrences of one of these concepts the average distance was 4.0 intermediary concepts (on average 2.5 for Emotion, 2.5 for Love, 1.0 for Happiness, 7.4 for Human, 3.7 for Organism, 4.9 for Biology and 5.8 for Family).

These shared seven concepts of eleven concepts have quite dominant role also in two additional vocabulary sets: all of these seven concepts belong to eleven highest-ranking concepts in respect to the number of unique recalled concepts in respect to hyperlinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration (shown in Appendix Z), and six of these seven concepts belong to eleven highest-ranking concepts in respect to the number of revisits to concepts in exploration paths when for each concept at most one revisit can be counted

for each student (shown in Table 5.18) when observing 55 concepts of “hyperlink network of 55 concepts”.

Figure 10.1 shows all 28 connecting hyperlinks (black solid arcs) between the set of eleven highest-ranking concepts of recalled selected concepts (red concepts) in “hyperlink network of 55 concepts” containing altogether 212 hyperlinks. In addition the figure is supplied with five additional concepts of which three belong to the set of eleven highest-ranking concepts of shown concepts (purple concepts Oxygen, Religion and Plant) and two belong to the set of eleven highest-ranking concepts of encountered (actively selected) concepts (turquoise concepts Experience and Death). 17 green dotted arcs show all hyperlinks connecting between these five additional concepts and connecting these five additional concepts to set of eleven highest-ranking concepts of recalled selected concepts in “hyperlink network of 55 concepts”. Seven concepts that are shared by all three high-ranking vocabulary sets of eleven concepts (recalled selected concepts, shown concepts and encountered (actively selected) concepts) are indicated with an asterisk (*).

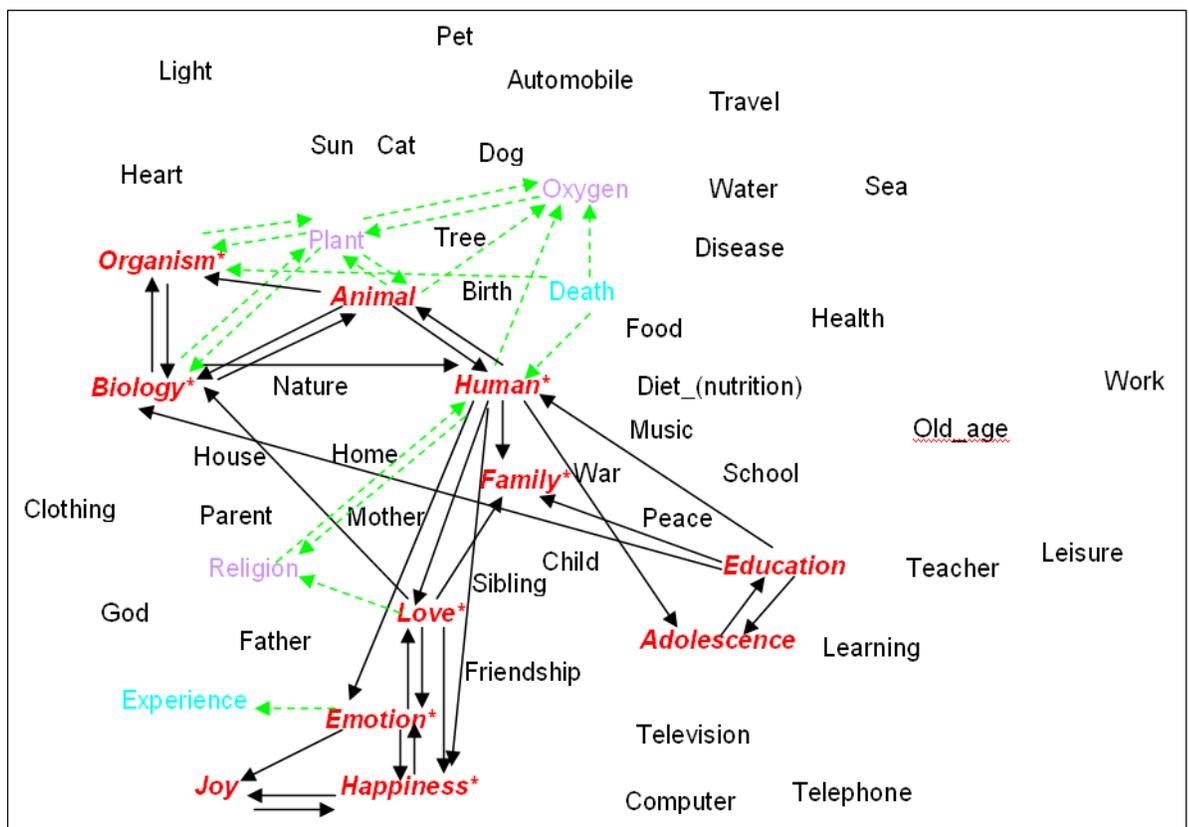


Figure 10.1. This figure shows all 28 connecting hyperlinks (black solid arcs) between the set of eleven highest-ranking concepts of recalled selected concepts (red concepts) in “hyperlink network of 55 concepts” containing altogether 212 hyperlinks. In addition the figure is supplied with five additional concepts of which three belong to the set of eleven highest-ranking concepts of shown concepts (purple concepts) and two belong to the set of eleven highest-ranking concepts of encountered (actively selected) concepts (turquoise concepts). 17 green dotted arcs show all hyperlinks connecting between these five additional concepts and connecting these five additional concepts to set of eleven highest-ranking concepts of recalled selected concepts in “hyperlink network of 55 concepts”. Seven concepts that are shared by all three high-ranking vocabulary sets of eleven concepts (recalled selected concepts, shown concepts and encountered (actively selected) concepts) are indicated with an asterisk (*).

We suggest that in Figure 10.1 eleven highest-ranking recalled selected concepts and connecting hyperlinks between them can possibly coarsely represent how memories and cumulative understanding is formed in human mind during a learning process so that a learner is exposed to a set of concepts that is in current case represented by a set of 55 concepts and that depending on various properties of learning session and amount of exposure some relationships become established and reinforced between certain pairs of concepts inside this set of 55 concepts. We think that here eleven highest-ranking recalled selected concepts and connecting hyperlinks between them can be seen to form an *emerging fundamental grid for a conceptual network* that offers a convenient cluster structure so that information can be managed efficiently in a compact and easily updateable form in human mind. We think that in Figure 10.1 five additional concepts (three shown concepts and two encountered (actively selected) concepts) and linkage between them and connecting them to the set of eleven highest-ranking recalled selected concepts can be seen as a potential area for cumulative future growth of the fundamental grid for a conceptual network so that these five additional concepts could possibly become adopted next and thus could become then considered as recalled selected concepts as well.

We suggest that knowledge adoption in human mind could gradually proceed during learning process so that eventually all 55 concepts could have become connected to same entity of fundamental grid for a conceptual network in a way that resulting conceptual network could somewhat resemble “hyperlink network of 55 concepts” that we have generated based on hyperlink network of the Wikipedia containing 212 hyperlinks connecting 55 concepts as shown in Appendix J. Naturally different learners and learning processes can lead to different network structures and there can be various parallel, overlapping and multidimensional conceptual networks in human mind to represent knowledge but we suggest that fundamental principles governing knowledge adoption and management in human mind can be based on structures and processes we have proposed with a conceptual network model that is illustrated with an example that we refer to as “hyperlink network of 55 concepts”.

It is interesting to note that while each student made in “hyperlink network of 55 concept” an exploration path traversing 20 hyperlink steps she eventually managed to recall on average 11.33 unique concepts of on average 34.16 unique shown concepts (each shown on average 5.08 times) and when observing linkage between a set of eleven highest-ranking recalled selected concepts of all 49 students participating the experiment there were 28 connecting hyperlinks between these eleven highest-ranking recalled selected concepts (so number of steps (20) appears to be relatively close to number of connecting hyperlinks (28)).

While among all 55 concepts of “hyperlink network of 55 concepts” there is on average 3.85 departing hyperlinks and 3.85 arriving hyperlinks interconnecting these 55 concepts (shown in Table 5.12), the set of eleven highest-ranking recalled selected concepts (Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal) has on average 5.82 departing hyperlinks and 6.64 arriving hyperlinks connecting to 55 concepts of “hyperlink network of 55 concepts”.

Furthermore, five additional concepts that we think might possibly become adopted next (Oxygen, Religion, Plant, Experience and Death) have on average 4.8 departing hyperlinks and 6.2 arriving hyperlinks connecting to 55 concepts of “hyperlink network of 55 concepts”. We suggest that here higher average amount of interconnecting links for recalled selected concepts indicates that it is easier to recall such concepts that have highly linked position in hyperlink network of vocabulary and thus these concepts can have diverse associative paths to other concepts and can get high number of visits during exploration in hyperlink network possibly due to serving as some kind of hub in the network.

Figure 10.1 can be compared with Figure 6.3 showing 55 concepts primarily supplied with highest-ranking departing hyperlink and highest-ranking arriving hyperlink in respect to five alternative statistical features of corresponding Wikipedia articles (including hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate and edits per article size). It seems that the set of eleven highest-ranking recalled selected concepts are relatively highly inter-connected also based on hyperlinks listed in Figure 6.3 which might indicate that also properties of five alternative statistical features can have some kind of contribution to which concepts can become recalled well after exploration in hyperlink network. Also it is possible that recalling a concept after exploration in hyperlink network depends on what is the ranking of this concept in general high-frequency word list of current language and at how early in life and how much a person has become exposed to this concept and how meaningful it is to him personally, as motivated by previous research ((Izura & Ellis 2002); (Ellis & Lambon 2000)).

Among the set of eleven highest-ranking recalled selected concepts there appears to be on average 4.64 interconnecting hyperlinks (2.36 departing hyperlinks and 2.27 arriving hyperlinks) for each of eleven concepts: Human (7 hyperlinks: 5 departing + 2 arriving), Love (6 hyperlinks: 4 departing + 2 arriving), Emotion (6 hyperlinks: 3 departing + 3 arriving), Happiness (6 hyperlinks: 2 departing + 4 arriving), Education (5 hyperlinks: 4 departing + 1 arriving), Animal (5 hyperlinks: 3 departing + 2 arriving), Biology (5 hyperlinks: 2 departing + 3 arriving), Adolescence (3 hyperlinks: 1 departing + 2 arriving), Joy (3 hyperlinks: 1 departing + 2 arriving), Family (3 hyperlinks: 0 departing + 3 arriving), and Organism (2 hyperlinks: 1 departing + 1 arriving).

Based on Table 10.9 and Table 10.7 in “hyperlink network of 55 concept” an exploration path while traversing 20 hyperlink steps offers for the student on average 101.51 shown concepts (of which 34.16 are unique concepts meaning showing each of them about 2.97 times), thus on average 5.08 shown concepts per each hyperlink step (i.e. at each concept there are on average 5.08 alternative hyperlinked concepts available to be traversed next), and along traversing 20 hyperlink steps the student encounters on average 13.80 unique (actively selected) concepts meaning encountering each of them on average 1.45 times. Based on Table 10.9 we estimated that for the set of eleven highest-ranking recalled selected concepts (Emotion, Love, Happiness, Human, Organism, Biology, Family, Joy, Education, Adolescence and Animal) each of these eleven concepts is shown (i.e. not necessarily actively selected but shown) along exploration path of 20 hyperlink steps on average 3.75 times, thus on average 0.19 times

shown per each hyperlink step, and is encountered (actively selected) along exploration path of 20 hyperlink steps on average 0.49 times, thus on average 0.02 times per each hyperlink step.

Based on Table 10.7 it can be also seen that student can recall on average 11.33 unique concepts of 34.16 unique shown concepts (33 percent of unique shown concepts), and can recall on average 8.94 unique concepts of those unique shown concepts that are also actively selected (26 percent of unique shown concepts). It appears that about 79 percent ($8.94/11.33 \approx 0.79$) of unique recalled concepts are actively selected along exploration path and remaining 21 percent are just shown during exploration path but not actively selected. Anyway student on average can recall 8.94 unique concepts of 13.80 unique encountered (actively selected) concepts thus meaning that she can recall 65 percent of unique encountered (actively selected) concepts.

When estimating from Table 10.9 for the three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” what is the range of average amount of interaction with each set of concepts for each of 49 students along exploration path, it appears that eleven highest-ranking shown concepts are shown on average 3.29–5.37 times per each student, eleven highest-ranking recalled selected concepts are recalled on average 0.27–0.49 times per each student, and eleven highest-ranking encountered (actively selected) concepts are encountered (actively selected) on average 0.43–0.61 times per each student. Even if the three sets of eleven highest-ranking concepts do not share exactly same concepts (sharing 7 of 11 concepts) we think that these values can possibly indicate a somewhat minimal level of interaction that a student should have with concepts along exploration path so that these concepts can be sufficiently become adopted. We think that especially interesting is that when considering eleven highest-ranking recalled selected concepts and their corresponding values of average number of times they are shown per each student, nine of these have been shown at least 3.18 times and two concepts additionally gained a bit lower values (Education shown 1.88 times and Joy shown 1.90 times).

Some of the estimates about properties of exploration paths in hyperlink network that have been gained in exploration task and that have been just discussed are shown in Table 10.10. Please note that just discussed features related to three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and features shown in Table 10.10 can be considered to at least indirectly give strong experimental support to our suggestions of Publication [P7] (as will be discussed in Subchapter 12.1) that the student’s exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning. We have carried out an extended analysis just discussed in this current Subchapter 10.2 after publishing publication [P7] and therefore our these supplementing later experiments seem to fruitfully verify findings of our earlier preliminary testing we reported in publication [P7] including suggested approximate values for parameters of the proposed framework for spaced learning with exploration in hyperlink network of the Wikipedia.

Based on Table 10.9 for each of five comparison tests Table 10.11 shows if its null hypothesis becomes rejected or becomes not rejected based on significance level of $p < 0.05$ when estimating *degrees of dependency* between 55 concepts of “hyperlink

network of 55 concepts” based on three rankings: number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration and number of unique encountered (actively selected) concepts during exploration.

Table 10.10. Some estimates about properties of exploration paths in hyperlink network that have been gained with experiment group (n=49) of exploration experiment.

When a student traverses an exploration path containing 20 hyperlink steps inside “hyperlink network of 55 concepts”
- “hyperlink network of 55 concepts” contains 212 hyperlinks connecting 55 concepts based on hyperlink network of the Wikipedia
- along 20 hyperlinks steps of exploration path at each concept there are on average 5.08 alternative hyperlinked concepts available to be traversed next
- along 20 hyperlinks steps there are on average 101.51 shown concepts (of which on average 34.16 are unique concepts meaning showing each of them about 2.97 times)
- from the set of 34.16 unique shown concepts about 11.33 can be recalled
- along 20 hyperlinks steps on average 13.80 unique concepts become actively selected meaning selecting each of them about 1.45 times
- from the set of 13.80 unique actively selected concepts about 8.94 can be recalled
- student can recall about 11.33 unique concepts of 34.16 unique shown concepts (33 percent of unique shown concepts); - student can recall about 8.94 unique concepts of those unique shown concept that are also actively selected (26 percent of unique shown concepts); - thus about 79 percent (8.94/11.33) of unique recalled concepts are actively selected along exploration path and remaining about 21 percent are just shown but not actively selected; - student can recall about 8.94 unique concepts of 13.80 unique actively selected concepts (65 percent of unique actively selected concepts)
- corresponding to recalled 11.33 unique shown concepts it was estimated that eleven highest-ranking shown concepts are shown on average 3.29–5.37 times per each student, eleven highest-ranking recalled selected concepts are recalled on average 0.27–0.49 times per each student, and eleven highest-ranking actively selected concepts are actively selected on average 0.43–0.61 times per each student

To facilitate identifying possible similarities between frequency distributions of Table 10.9 we transformed for representation of Table 10.11 the frequency values into approximately same range of values thus forming scaled frequency distributions so that sign test of paired samples between this pair of distributions produces a p-value that is as high as possible and thus as an outcome the difference in medians between this pair of scaled frequency distributions is as small as possible. Therefore we decided that scaled frequency distribution of number of times hyperlinked concepts are shown to student during exploration has a weighting parameter 1; scaled frequency distribution of number of recalled concepts in respect to hyperlinked concepts that are shown to student during exploration has a weighting parameter 11; and scaled frequency distribution of number of encountered concepts during exploration has a weighting parameter 7. In brief, we created each scaled frequency distributions so that we multiplied each frequency value of original frequency distribution by the weighting parameter defined for this distribution.

Table 10.11. Degrees of dependency between 55 concepts of “hyperlink network of 55 concepts” based on three rankings: number of times hyperlinked concepts are shown (i.e. not necessarily actively selected but shown) to student during exploration, number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration and number of unique encountered (actively selected) concepts during exploration.

Compared pair of distributions		Tests based on scaled frequency values		Tests based on ranking values		
<i>Distribution A</i>	<i>Distribution B</i>	<i>Sign test of paired samples</i>	<i>Bootstrap version of Kolgomorov-Smirnov two-sample test</i>	<i>Goodman-Kruskal gamma statistic</i>	<i>Spearman's rank correlation coefficient rho</i>	<i>Kendall's rank correlation coefficient tau</i>
number of times hyperlinked concepts are shown to student during exploration (scaled)	number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.899 (null hypothesis Hks not rejected)	gamma=0.6139106 (standard error 0.1559587); null hypothesis Hgk rejected (p=8.272444×10 ⁻⁵)	rho=0.7766964; null hypothesis Hsr rejected (p=3.184×10 ⁻¹²)	tau=0.5993631; null hypothesis Hkr rejected (p=2.949×10 ⁻¹⁰)
number of times hyperlinked concepts are shown to student during exploration (scaled)	number of unique encountered (actively selected) concepts during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.899 (null hypothesis Hks not rejected)	gamma=0.5879888 (standard error 0.1585215); null hypothesis Hgk rejected (p=0.0002079098)	rho=0.7495532; null hypothesis Hsr rejected (p=4.576×10 ⁻¹¹)	tau=0.5785372; null hypothesis Hkr rejected (p=9.067×10 ⁻¹⁰)
number of unique recalled concepts in respect to unique hyperlinked concepts that are shown to student during exploration (scaled)	number of unique encountered (actively selected) concepts during exploration (scaled)	p=1 (null hypothesis Hst not rejected)	p=0.899 (null hypothesis Hks not rejected)	gamma=0.7570499 (standard error 0.1302929); null hypothesis Hgk rejected (p=6.233561×10 ⁻⁹)	rho=0.8614709; null hypothesis Hsr rejected (p < 2.2×10 ⁻¹⁶)	tau=0.7342476; null hypothesis Hkr rejected (p=2.243×10 ⁻¹⁴)

We examined how the student’s performance on recalling hyperlinked concepts was related to different background parameters gained together with the student’s response. Table 10.12 shows recalling performance in respect to the gender of the student. Table 10.13 shows recalling performance in respect to comparing the adoption of knowledge through reading with the method to traditional learning from book. Table 10.14 shows recalling performance in respect to if the student is interested in using the method for adoption of knowledge trough reading. Table 10.15 shows recalling performance in respect to how easy it is for the student to adopt knowledge through reading. Table 10.16 shows recalling performance in respect to the students school performance.

Table 10.12. Recalling hyperlinked concepts in respect to gender of the student.

Gender	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Male and female	49	0.331541	0.01333	49	0.647929	0.041465
Male	18	0.274824	0.002635	18	0.587936	0.015385
Female	31	0.364474	0.016784	31	0.682764	0.054213
Gender	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Male and female	24	0.329657	0.009401			
Male	12	0.289216	0.006737			
Female	12	0.370098	0.009352			

Table 10.13. Recalling hyperlinked concepts in respect to response to question: “If you compare to traditional learning from a book, then the method you have just tried for adopting knowledge through reading appears to be...”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Somewhat more or much more useful	27 (23+4)	0.341497	0.014961	27 (23+4)	0.687267	0.042991
Equally useful	15	0.314178	0.014378	15	0.570217	0.047187
Somewhat less or much less useful	7 (6+1)	0.330346	0.007058	7 (6+1)	0.662722	0.01301
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Somewhat more or much more useful	8 (6+2)	0.3125	0.013825			
Equally useful	10	0.323529	0.006728			
Somewhat less or much less useful	6 (5+1)	0.362745	0.009919			

Table 10.14. Recalling hyperlinked concepts in respect to response to question: “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
It is probable or very probable	24 (20+4)	0.326862	0.010406	24 (20+4)	0.682569	0.038797
Perhaps	21	0.330346	0.019033	21	0.600592	0.049464
It is improbable or very improbable	4 (2+2)	0.36589	0.004855	4 (2+2)	0.688609	0.008757
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
It is probable or very probable	5 (3+2)	0.317647	0.008391			
Perhaps	12	0.291667	0.00715			
It is improbable or very improbable	7 (5+2)	0.403361	0.007991			

Table 10.15. Recalling hyperlinked concepts in respect to response to question: “How easy it is for you to adopt new knowledge through reading?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Easy or very easy	24 (21+3)	0.368329	0.012138	24 (21+3)	0.709751	0.031972
Moderate	18	0.295964	0.01521	18	0.575855	0.054687
Difficult or very difficult	7 (5+2)	0.296894	0.006406	7 (5+2)	0.621302	0.022518
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Easy or very easy	7 (6+1)	0.336134	0.002842			
Moderate	15	0.319608	0.012589			
Difficult or very difficult	2 (2+0)	0.382353	0.015571			

Table 10.16. Recalling hyperlinked concepts in respect to response to question: “In your opinion, how successfully do you perform at school?”

Opinion	Experiment group: Recalling hyperlinked concepts shown to the student (n=49)			Experiment group: Recalling hyperlinked concepts actively selected by the student (n=49)		
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>	<i>n_i</i>	<i>Average</i>	<i>Variance</i>
Well or excellently	23 (18+5)	0.370344	0.014691	23 (18+5)	0.693337	0.038606
Satisfactorily	22	0.316661	0.006254	22	0.652367	0.027021
Fairly or faintly	4 (4+0)	0.190263	0.021991	4 (4+0)	0.362426	0.066552
Opinion	Control group: Recalling concepts shown to the student (n=24)					
	<i>n_i</i>	<i>Average</i>	<i>Variance</i>			
Well or excellently	10 (9+1)	0.35	0.014504			
Satisfactorily	14	0.315126	0.006046			
Fairly or faintly	0 (0+0)	0	0			

10.3. Recall of shown hyperlinks forming the shortest paths in hyperlink network after exploration task

We carried out additional supplementary experiments with students to verify suggested benefits of our proposed method to support educational exploration in conceptual network based on hyperlink network of the Wikipedia. We provide now results of our experiment concerning *recall of shown hyperlinks forming the shortest paths in hyperlink network after exploration task*.

As already motivated in Subchapter 5.2, experimental setup for recall of shown hyperlinks forming the shortest paths in hyperlink network discussed here in Subchapter 10.3 can be considered to support learners representing cognitive style of *field dependence* whereas experimental setup for recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network discussed in Subchapter 10.2 can be considered to support learners representing cognitive style of *field independence*.

We aimed to carry out experiments with a sufficiently compact educational topic that most preferably was not previously well known among the students participating in our experiment but still could be understood relatively easily based on basic everyday knowledge and explained with a relatively simple vocabulary. Thus we decided to have

a learning topic that was dealing with cultural history related to a certain quite small geographic area and we ended up choosing that this area is European state of Malta.

We extracted in June 2014 a subsection of hyperlink network of Wikipedia about state of Malta so that we first extracted all 3278 Wikipedia articles belonging to Wikipedia category Malta (<http://en.wikipedia.org/wiki/Category:Malta>). These 3278 articles had 226329 departing hyperlinks and of them 185610 were unique. Among these 185610 unique hyperlinks 20757 had an end concept belonging to group of 3278 Wikipedia articles belonging to Wikipedia category Malta. Thus there were 20757 unique hyperlinks interconnecting all 3278 articles belonging to category Malta but only 3011 articles of all 3278 articles became actually connected. These 20757 unique hyperlinks contained 2929 unique start concepts and 2274 unique end concepts. Among 20757 unique hyperlinks, for 4903 hyperlinks there was another hyperlink going into opposite direction. If all 20757 unique hyperlinks are allowed to be traversed in both actual linking direction and in opposite direction we get together 36597 unique hyperlinks that interconnect 3011 articles of category Malta. When eliminating from these 36597 unique hyperlinks those hyperlinks that are connected to article “Index of Malta related articles” we have 35688 unique hyperlinks.

To carry out a sufficiently compact educational exploration task in hyperlink network of Wikipedia articles belonging to category Malta we decided to observe how students explore the shortest connecting paths between two specific concepts that we considered to represent relatively general knowledge concerning the chosen learning topic of Malta. Therefore we decided to observe exploration of *the shortest paths leading from concept Tourism in Malta to concept Maltese euro coins*. We made an assumption that an average student knows that Malta is a state that can be visited as a tourist and that this knowledge can be used as a useful starting point of exploration path for adopting more knowledge about Malta. So even if the student has very limited previous knowledge about Malta it can be practical to enable the student to take a perspective based on tourism when starting to learn about a state or culture previously unknown to him and thus to use Tourism in Malta as the starting point of exploration path. We chose Maltese euro coins as the ending point of exploration path since we considered that euro coins are some concrete objects related to Malta that can be encountered in everyday life of students and thus can make learning topic more personally touching and meaningful (especially since students participating in our experiment live in a euro zone country similarly as Malta is a euro zone country thus having shared euro currency and since euro coins have nationally distinctive versions of decorations).

In just described hyperlink network of 35688 unique hyperlinks we generated the shortest paths leading from concept Tourism in Malta to concept Maltese euro coins. To generate the shortest paths in hyperlink network showing them in decreasing order of length of the path and also showing all alternative parallel paths having equal length we used Yen’s algorithm to compute top k shortest loopless paths with sufficiently high values of k (Yen 1971).

It turned out that in our hyperlink network the shortest path from Tourism in Malta to Maltese euro coins has the length of two hyperlinks and traverses concept Malta, i.e.

this shortest path is Tourism in Malta → Malta → Maltese euro coins. Since we wanted to create an exploration task that covers the chosen learning topic Malta more broadly than just this single shortest path can, we decided to take into consideration only shortest paths having the length of three hyperlinks and additionally excluding all shortest paths that traverse concept Malta. It turned out that from Tourism in Malta to Maltese euro coins there are 29 alternative shortest paths having length of three hyperlinks and after exclusion of paths traversing concept Malta there are 11 alternative shortest paths. These eleven shortest paths are shown in Table 10.17.

Table 10.17. 11 alternative shortest paths having length of three hyperlinks leading from concept Tourism in Malta to concept Maltese euro coins.

<i>Hyperlink chains of shortest paths</i>
Tourism in Malta → Knights Hospitaller → Coat of arms of Malta → Maltese euro coins
Tourism in Malta → Outline of Malta → Coat of arms of Malta → Maltese euro coins
Tourism in Malta → Gozo → History of Malta → Maltese euro coins
Tourism in Malta → Knights Hospitaller → History of Malta → Maltese euro coins
Tourism in Malta → Outline of Malta → History of Malta → Maltese euro coins
Tourism in Malta → Valletta → History of Malta → Maltese euro coins
Tourism in Malta → Knights Hospitaller → Maltese cross → Maltese euro coins
Tourism in Malta → Economy of Malta → Maltese lira → Maltese euro coins
Tourism in Malta → Government of Malta → Maltese lira → Maltese euro coins
Tourism in Malta → Marsaxlokk → Maltese lira → Maltese euro coins
Tourism in Malta → Valletta → Maltese lira → Maltese euro coins

To help to ensure that it is easy for the students to understanding all concepts mentioned in these eleven shortest paths, we transformed spelling of some them. Concept Maltese euro coins was changed to spelling Euro coins of Malta, concept Coat of arms of Malta was changed to spelling Official state symbol of Malta, concept Maltese cross was changed to spelling Cross of Malta, concept Maltese lira was changed to spelling Lira of Malta, concept Knights Hospitaller was changed to spelling Knights of Malta, and concept Outline of Malta was changed to spelling Overview of Malta. Just mentioned 11 shortest paths with transformed spelling can be seen visualized in Figure 10.2 when chaining these following 11 series of three hyperlinks: 1, 8, 19; 2, 9, 19; 3, 10, 21; 4, 11, 22; 4, 12, 21; 4, 13, 24; 5, 14, 19; 6, 15, 21; 6, 16, 24; 7, 17, 21; and 7, 18, 19.

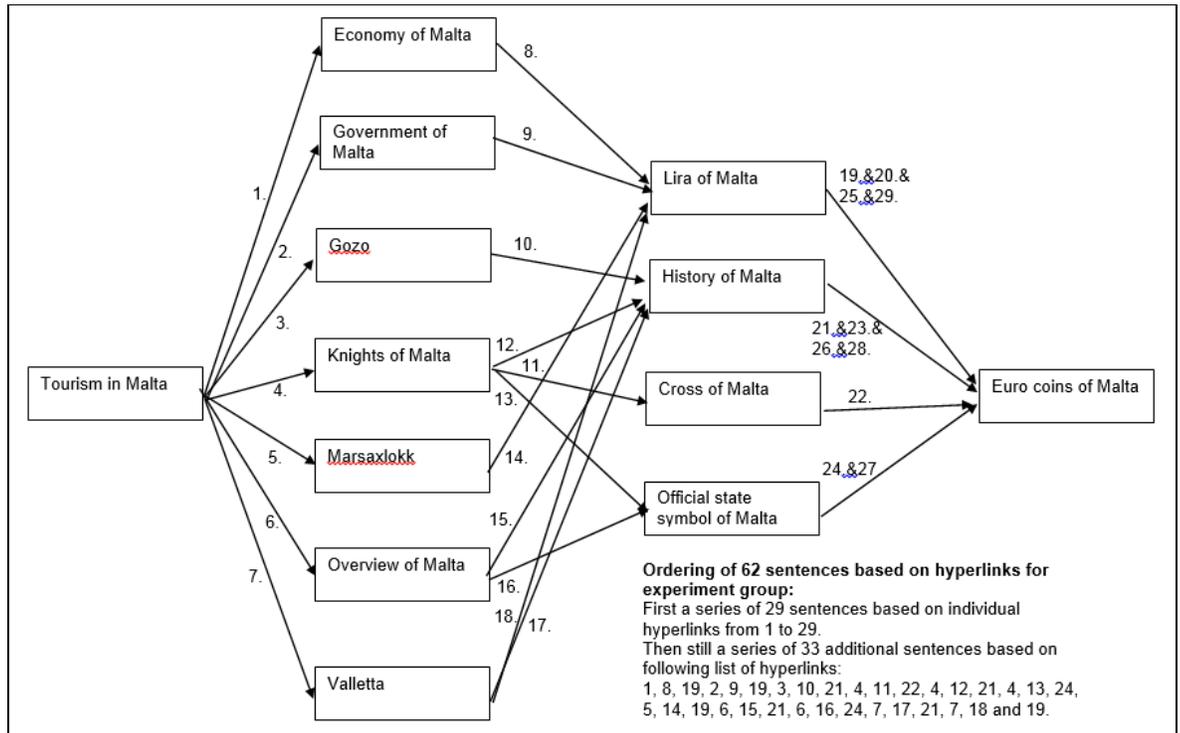


Figure 10.2. Visualization of 11 alternative shortest paths having length of three hyperlinks leading from concept Tourism in Malta to concept Euro coins of Malta (some spelling transformed to ensure easy understanding). This figure also explains ordering of the series of 62 sentences of hyperlinks for experiment group.

To depict semantic relationship of each pair of hyperlinked concepts, for each hyperlink we extracted a *relation statement* from sentence surrounding the departing hyperlink in article text. If suitable sentence was not available, we generated relation statement based on other contextual text segments relatively near the hyperlink anchor or possibly based on relation statement we created for another hyperlink going into opposite direction. For example relation statement for hyperlink going from Tourism in Malta to Economy of Malta is “forms about 15 percent of” which should be interpreted so that “Tourism in Malta forms about 15 percent of Economy of Malta”. Appendix AG shows all these 11 shortest paths supplied with relation statements for each hyperlink.

We carried out an exploration experiment with a group of 34 students having ages ranging from 15 to 19 years and having learning abilities that can be considered normal. We compared two learning cases by asking an experiment group (n=24) and a control group (n=10) to perform an exploration task. Please note that all these 34 students belonging to either experiment group or control group discussed in this Subchapter 10.3 consist of completely different people than experiment group and control group that were discussed in Subchapter 10.2 and also different people than group of 103 students which was explained in Subchapter 3.9 (i.e. there is no overlap of persons for these five experimental groups: group of 103 students explained in Subchapter 3.9, experiment group and control group explained in Subchapter 10.2 as well as experiment group and control group explained in Subchapter 10.3).

The students performed exploration task in English language based on English Wikipedia. Before the exploration experiment started we asked with a background

questionnaire (shown in Appendix AM) each student to report her gender and age as well as how easy it is for her to adopt knowledge through reading and how successfully she performs at school (see Table 10.18, Table 10.19 and Table 10.20). The two last mentioned questions were replied by selecting a most suitable answer from a scale of five given alternatives.

Based on these four responses we tried our best to form experiment group and control group so that they share approximately same background characteristics, especially in respect to age, adoption ability and school performance. It should be noted that these estimates about adoption ability and school performance are self-reported by students and thus for example self-critical students may have underestimated their skills. We decided to include about two thirds of students to experiment group and one third to control group.

Table 10.18. The number, age and gender distribution of students in experiment group and control group.

Value	Experiment group (n=24)			Control group (n=10)		
	Male and female	Male	Female	Male and female	Male	Female
Number of students	24 (100 %)	9 (%)	15 (%)	10 (100 %)	2 (%)	8 (%)
Average of ages (years)	16.27 (n=22)*	16.14 (n=7)*	16.33 (n=15)	16.40	17.50 ()	16.13 ()
Variance of ages	1.45	0.81	1.81	2.04	0.50	2.13

Table 10.19. Responses to question “How easy it is for you to adopt new knowledge through reading?”

Opinion	Experiment group (n=24)				Control group (n=10)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Very easy	4.8 % (n=21)*	1 (n=21)*	1 (n=7)*	0 (n=14)*	0 %	0	0	0
Easy	47.6 % (n=21)*	10 (n=21)*	1 (n=7)*	9 (n=14)*	50 %	5	0	5
Moderate	47.6 % (n=21)*	10 (n=21)*	5 (n=7)*	5 (n=14)*	50 %	5	2	3
Difficult	0 % (n=21)*	0 (n=21)*	0 (n=7)*	0 (n=14)*	0 %	0	0	0
Very difficult	0 % (n=21)*	0 (n=21)*	0 (n=7)*	0 (n=14)*	0 %	0	0	0

Table 10.20. Responses to question “In your opinion, how successfully do you perform at school?”

Opinion	Experiment group (n=24)				Control group (n=10)			
	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)	Male and female (percent)	Male and female (persons)	Male (persons)	Female (persons)
Excellently	9.5 % (n=21)*	2 (n=21)*	1 (n=7)*	1 (n=14)*	10 %	1	0	1
Well	47.6 % (n=21)*	10 (n=21)*	3 (n=7)*	8 (n=14)*	50 %	5	1	4
Satisfactorily	38.1 % (n=21)*	8 (n=21)*	3 (n=7)*	5 (n=14)*	40 %	4	1	3
Fairly	0 % (n=21)*	0 (n=21)*	0 (n=7)*	0 (n=14)*	0 %	0	0	0
Faintly	0 % (n=21)*	0 (n=21)*	0 (n=7)*	0 (n=14)*	0 %	0	0	0

During one day both members of experimental group and control group participated in *three separate learning sessions* and each of these sessions consisted of a *pre-test*, a *silent reading task* and a *post-test* based on same fundamental knowledge structure although presented to students in somewhat varied form. For both experimental group and control group the silent reading task in each of three learning sessions was to read

once through a series of 62 sentences built by using 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta in hyperlink network of Wikipedia category Malta. Each of 22 unique hyperlinks were presented as a sentence consisting of its start concept, relation statement and end concept. Appendix AH lists each of 22 unique hyperlinks with its sentence and shows the identification number coding that we used to create different orderings and variations of these sentences for text material used for silent reading task as well as pre-test and post-test for both experiment group and control group.

For members of the *experiment group* (n=24) the series of 62 sentences was made to be identical for each of three learning sessions (shown in Appendix AI). Here 62 sentences were chained in such an ordering that corresponds to traversing cumulatively a series of associative trails leading from concept Tourism in Malta to concept Euro coins of Malta along alternative parallel shortest paths in hyperlink network of Wikipedia category Malta. Figure 10.2 illustrates the ordering of the series of 62 sentences for experiment group. So the idea of this ordering is to first introduce the first hyperlink step for each of 11 shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta, next to introduce the second hyperlink step for each of 11 shortest paths, then to introduce the third hyperlink step for each of 11 shortest paths, and after that finally to introduce one by one the full routes of each of 11 shortest paths (thus showing three consecutive hyperlink steps belonging to each of 11 shortest paths).

In each of three learning sessions before and after the silent reading task each member of experiment group was asked to fill in a *multiple-choice questionnaire* that measured recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta in hyperlink network of Wikipedia category Malta. These pre-tests 1-3 and post-tests 1-3 (that we also call as *measurements 1-6*) contained always the same 22 multiple-choice items, each item corresponding to each of 22 unique hyperlinks and having four alternative answers we had created so that only one of them is correct. For example a multiple-choice item corresponding to hyperlink Tourism in Malta → Economy of Malta had for alternative answers: Tourism in Malta forms about 10 percent of Economy of Malta; Tourism in Malta forms about 12 percent of Economy of Malta; Tourism in Malta forms about 15 percent of Economy of Malta; Tourism in Malta forms about 17 percent of Economy of Malta (here the third alternative is correct).

Please note that the student fills in the multiple-choice questionnaire first time before she has yet read the silent reading task and this pre-test 1 (i.e. measurement 1) is supposed to measure the student's previously acquired knowledge about learning topic before the exploration task has yet started (i.e. starting level for adoption of new knowledge). Each of six multiple-choice questionnaires given during exploration task have different randomized ordering for 22 multiple-choice items (but in each multiple-choice item the four answer alternatives and their ordering always remain the same in each of six questionnaires). Appendix AJ shows six different multiple-choice questionnaires that were used for pre-tests 1-3 and post-tests 1-3 (i.e. measurements 1-6) for both members of experiment group and members of control group.

In contrast with the experiment group, for members of the *control group* (n=10) the series of 62 sentences was made to have randomized ordering of sentences for each of three learning sessions. The idea of this randomization is to enable comparison of control group with experiment group which (as just explained) becomes in each three learning sessions exposed to the series of 62 sentences in such chained ordering that corresponds to traversing cumulatively a series of associative trails leading from concept Tourism in Malta to concept Euro coins of Malta along alternative parallel shortest paths in hyperlink network. Appendix AK shows three different series of 62 sentences having randomized ordering that were used for silent reading task of members of control group.

In each of three learning sessions before and after the silent reading task each member of control group was asked to fill in a multiple-choice questionnaire that measured recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta. Each of six multiple-choice questionnaires given during exploration task have different randomized ordering for 22 multiple-choice items (but in each multiple-choice item the four answer alternatives and their ordering always remain the same in each of six questionnaires).

For both experiment group and control group the randomization of ordering of multiple-choice items in six questionnaires of pre-tests and post-tests aims to prevent emergence of such repeated chained ordering of multiple-choice items that might start to compete with the enforcing repetitions occurring in silent reading task of experiment group which corresponds to cumulatively traversing a series of associative trails in hyperlink network.

We carried out exploration task concurrently with experiment group and control group so that the *first learning session* was in the morning lasting from 10:00 to 10:20, the *second learning session* was in the afternoon lasting from 16:30 to 16:50 (i.e. 6 hours 30 minutes after the first session) and the *third learning session* was in the evening lasting from 18:40 to 19:00 (i.e. 8 hours 40 minutes after the first session). Appendix AN shows full listing about how members of experiment group and members of control group answered to each multiple-choice questionnaire and what background information was gathered about these persons.

Based on the ratio of correct answers to wrong answers in multiple-choice questionnaires, Table 10.21 and Figure 10.3 show for both pre-test and post-test of each of three learning sessions the *degree of recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths* leading from concept Tourism in Malta to concept Euro coins of Malta. Here it appears in the first measurement that the members of control group can reach higher degrees of recall than experiment group but after that in the following five measurements the members of experiment group can reach higher degrees of recall than control group. It is positive to note that for both experiment group and control group the degree of recall seems to remain relatively high for quite long period of time even after just one exposure to knowledge and later exposures can further increase degree of adoption. The difference of degree of recall between experiment group and control group seems to be biggest for the third

measurement and then for the fourth measurement but after that the difference gets again lower values. An interesting phenomenon is that for experiment group the degree of recall seems to stay constant between measurements 2-3 and for control group the degree of recall seems to rise between measurements 4-5.

Table 10.21. Degree of recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

		Number of correctly recalled hyperlinks of 22 hyperlinks in 22 multiple-choice items of questionnaire					
		<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
		Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Experiment group	hyperlinks	7.71	15.38	15.35	17.55	17.00	18.14
	degree of recall	0.35	0.70	0.70	0.80	0.77	0.82
Control group	hyperlinks	8.20	14.60	13.40	15.70	16.56	17.33
	degree of recall	0.37	0.66	0.61	0.71	0.75	0.79

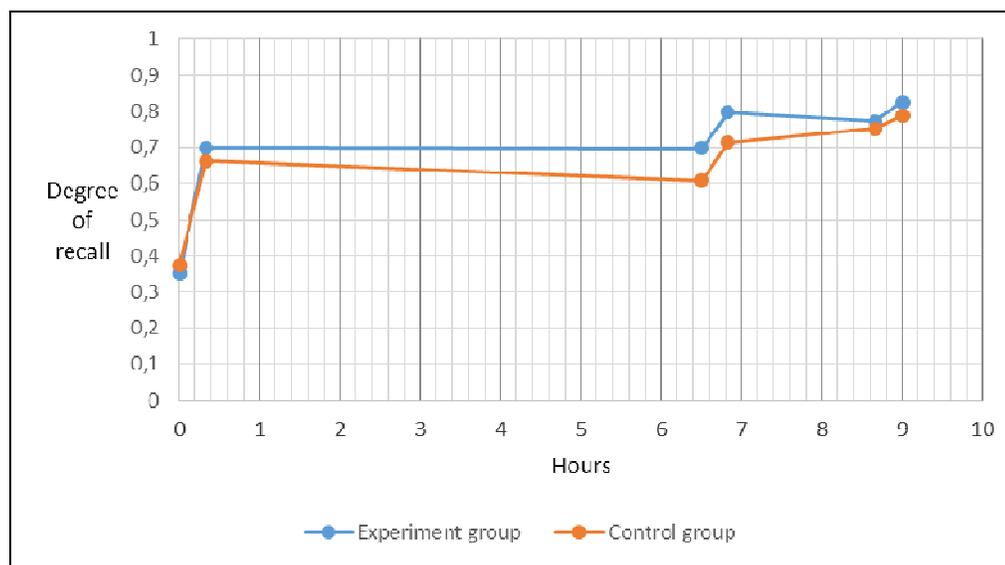


Figure 10.3. Degree of recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

Besides examining the degree of recall of individual relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta we wanted also to examine the *degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths* leading from concept Tourism in Malta to concept Euro coins of Malta. Appendix AL shows each of unique 22 pairs of consecutive hyperlinks

that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

Table 10.22 and Figure 10.4 show degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta. This means that now the student has to recall in the same measurement pairs of consecutive hyperlinks, for example based on Figure 10.2 one possible pair can be hyperlinks 1 and 8 or pair of hyperlinks 8 and 19 (these both pairs belong to the shortest path Tourism in Malta → Economy of Malta → Maltese lira → Maltese euro coins). Here it appears in the first measurement that the members of control group can reach higher degrees of recall than experiment group but after that in the following four measurements the members of experiment group can reach higher degrees of recall than control group and in the sixth measurement experiment group and control group have the same value of degree of recall. It is positive to note that for both experiment group and control group the degree of recall seems to remain relatively high for quite long period of time even after just one exposure to knowledge and later exposures can further increase degree of adoption. The difference of degree of recall between experiment group and control group seems to be biggest for the third measurement and then for the fourth measurement but after that the difference gets again lower values. An interesting phenomenon is that for experiment group the degree of recall seems to rise between measurements 2-3 and for control group the degree of recall seems to rise between measurements 4-5.

Table 10.22. Degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

		Number of correctly recalled pairs of 22 pairs of consecutive hyperlinks in 22 multiple-choice items of questionnaire					
		<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
		Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Experiment group	hyperlinks	3.00	11.54	11.91	14.95	13.86	15.67
	degree of recall	0.14	0.52	0.54	0.68	0.63	0.71
Control group	hyperlinks	3.80	10.50	9.40	11.90	12.89	15.67
	degree of recall	0.17	0.48	0.43	0.54	0.59	0.71



Figure 10.4. Degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

In each of three learning sessions, the exploration task seems to offer a promising *timing structure* that processes same knowledge structure – although in different forms - in three consecutive phases including about 5 minutes for pre-test, about 10 minutes for silent reading task and about 5 minutes for post-test. We think that this our proposed timing practice has positive resemblance with several previous findings, including Harvey and Svoboda (Harvey & Svoboda 2007) showing that when a spine of synapse is stimulated to action potential also surrounding spines are more sensitive for stimulus for about 10 minutes, Kandel (Kandel 2001) showing that stimulation of synapses can be successfully triggered by 4–5 spaced puffs of serotonin leading to activation of genes establishing long-term memory, Fields (Fields 2005) showing that to activate a gene for long-term memory formation in a synapse there is a need for at least three action potentials at least 10 minutes apart and once the gene is activated it produces required proteins for about 30 minutes, and Tambini (Tambini et al. 2010) showing that during a rest following an associative encoding task the hippocampal-cortical correlations can predict later associative memory.

Since the effect that an intervention has on learning achievements of students has been often measured with effect size, we wanted to measure the *effect size of exploration task in favor of experiment group in contrast with control group* and also *the effect size along learning of experiment group and along learning of control group*. Based on 815 meta-analyses the average of effect sizes - which was 0.40 - has been suggested to be used as a benchmark between effects that need more consideration and effects that are worth having (Hattie 2009) and it has been suggested that teachers can accomplish on average an effect size of 0.20–0.40 on the student’s school achievement per year (Hattie 2009).

According to Hattie (Hattie 2009) effects sizes in range 0–0.15 correspond to developmental effects that can be achieved even without schooling, effect sizes in range 0.15–0.40 correspond to effects from a teacher in a typical year of schooling and effect

sizes above 0.40 correspond to effects of influences that can be expected to have the greatest impact on the student achievement outcomes. It has been shown that the average effect sizes of six main categories of influences (contributors) to learning according to Hattie's synthesis of 815 meta-analyses that are in range 0.23–0.49 (Hattie 2009) or according to Hattie's synthesis of 931 meta-analyses in range 0.23–0.47 (Hattie 2012).

We used two major approaches for measuring the effect size: in the first type of approach the effect size is difference between the mean outcome for the intervention group and mean outcome for the control group, divided by pooled sample standard deviation, and in the second type of approach the effect size is difference between the mean outcome in the end of intervention and mean outcome in the beginning of intervention, divided by pooled sample standard deviation (Hattie 2009).

With the first type of approach for measuring the effect size we estimated the *effect size in favor of degree of recall in experiment group in contrast with degree of recall in control group* by computing the difference of averages of degree of recall in experimental group and control group divided by square root of pooled variance. Table 10.23 shows effect size in respect to degree of recall of relation statements *for each of 22 unique hyperlinks* that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta, and Table 10.24 shows effect size in respect to degree of recall of relation statements *for each of unique 22 pairs of consecutive hyperlinks* that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

Both in Table 10.23 and Table 10.24 for the effect size in favor of experiment group in contrast with control group we got estimates that based on previous research of Hattie (Hattie 2009) in measurements 3-4 the effect sizes are over 0.40 corresponding to developmental effects with the greatest impact (worth having) and measurements 2 and 5-6 belong to range of 0.15–0.40 corresponding to developmental effects from a teacher in a typical year of schooling.

Table 10.23. Effect size in respect to degree of recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

	Number of correctly recalled hyperlinks of 22 hyperlinks in 22 multiple-choice items of questionnaire					
	<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
	Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Effect size in favor of degree of recall in experiment group in contrast with degree of recall in control group	-0.18298	0.186432	0.40179	0.411672	0.107309	0.165636

Table 10.24. Effect size in respect to degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

	Number of correctly recalled pairs of 22 pairs of consecutive hyperlinks in 22 multiple-choice items of questionnaire					
	<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
	Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Effect size in favor of degree of recall in experiment group in contrast with degree of recall in control group	-0.30976	0.187537	0.418071	0.482189	0.181495	0

With the second type of approach for measuring the *effect size we estimated the effect size in favor of degree of recall in measurements 2-5 in contrast with degree of recall in measurement 1* by computing the difference of averages of degree of recall in measurements 2-5 and measurement 1 divided by square root of pooled variance. Table 10.25 shows separately for both experiment group and control group the effect size in respect to degree of recall of relation statements *for each of 22 unique hyperlinks that*

form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta. Table 10.26 shows separately for both experiment group and control group the effect size in respect to degree of recall of relation statements *for each of unique 22 pairs of consecutive hyperlinks* that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

In Table 10.25 separately for both experiment group and control group for the effect size in favor of degree of recall in measurements 2-5 in contrast with degree of recall in measurement 1 we got estimates that based on previous research of Hattie (Hattie 2009) in measurements 2-6 the effect sizes are over 0.40 corresponding to developmental effects with the greatest impact (worth having). In Table 10.26 separately for both experiment group and control group for the effect size in favor of degree of recall in measurements 2-5 in contrast with degree of recall in measurement 1 we got estimates that based on previous research of Hattie (Hattie 2009) in measurements 2-6 the effect sizes are over 0.40 corresponding to developmental effects with the greatest impact (worth having).

Table 10.25. Effect size in respect to degree of recall of relation statements for each of 22 unique hyperlinks that form the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

For experiment group: Number of correctly recalled hyperlinks of 22 hyperlinks in 22 multiple-choice items of questionnaire						
	<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
	Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Effect size in favor of degree of recall in measurements 2-6 in contrast with degree of recall in measurement 1	0	1.47	1.43	1.63	1.60	1.63
For control group: Number of correctly recalled hyperlinks of 22 hyperlinks in 22 multiple-choice items of questionnaire						
	<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)	
	Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3
Effect size in favor of degree of recall in measurements 2-6 in contrast with degree of recall in measurement 1	0	1.34	1.06	1.36	1.52	1.42

Table 10.26. Effect size in respect to degree of recall of relation statements for each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

For experiment group: Number of correctly recalled pairs of 22 pairs of consecutive hyperlinks in 22 multiple-choice items of questionnaire						
<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)		
Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3	
Effect size in favor of degree of recall in measurements 2-6 in contrast with degree of recall in measurement 1	0	1.42	1.41	1.59	1.60	1.62
For control group: Number of correctly recalled pairs of 22 pairs of consecutive hyperlinks in 22 multiple-choice items of questionnaire						
<i>Learning session 1</i> (0 h – 0 h 20 min)		<i>Learning session 2</i> (6 h 30 min – 6 h 50 min)		<i>Learning session 3</i> (8 h 40 min – 9 h)		
Pre-test 1	Post-test 1	Pre-test 2	Post-test 2	Pre-test 3	Post-test 3	
Effect size in favor of degree of recall in measurements 2-6 in contrast with degree of recall in measurement 1	0	1.17	1.03	1.23	1.43	1.48

Chapter 11. Characteristics of human learning process and representation of knowledge

In publications [P1]–[P6] and [P9] we have proposed computational methods aiming to support a learner in adoption of knowledge and due to promising experimental results gained for those methods we think that it is important to still more relate our work to fundamental characteristics emerging in any typical learning situation. Thus we want to introduce a brief review about some fundamental characteristics that have been identified in previous research concerning *human learning process* and *representation of knowledge* and that according to us can be seen to offer both useful potential and challenging constraints for development of new educational activities based on conceptual networks especially in respect to computer-assisted education.

11.1. Adoption of vocabulary

Features of a learning process to adopt vocabulary of a language are naturally strongly language dependent, affected among other things by morphology, variants of dialects, conjugation and syntax. In our work we have decided to focus on findings concerning vocabulary of English language due to its dominant international position. In publications of previous research it appears that used terminology remains sometimes fuzzy and that parallel observations are not easy to compare. For example in research concerning human vocabulary it seems that term word is sometimes used when actually meaning a word family and thus some effects of this kind of unclarities may have also somewhat affected accuracy of conclusions that we have tried to do based on previous research.

Nation and Waring (Nation & Waring 1997) estimated that in *English lexicon* there are well over 54000 word families and an *educated adult native speaker* knows around 20000 of them. According to Nation and Waring (Nation & Waring 1997) however, the most frequent 3000 to 5000 word families typically cover around 90 percent of ordinary text and even more of spoken language, and thus mastering just this fraction of full vocabulary can already provide a strong basis for comprehension thus allowing efficient further learning from the context.

Thal et al. (1997) have experimentally measured mean number of *produced words* at each month during child's development ranging from 8-month-old to 30-month-old. When we visually interpreted from graph in publication of Thal et al. (1997) representing vocabulary for children classified having an average progress we concluded following coarse estimates: 8-month-olds can produce about 0 words, 12-month-olds about 10 words, 18-month-olds about 120 words, 24-month-olds about 400 words and 30-month-olds about 560 words. Despite of somewhat confusing notations

we visually interpreted from graph in publication Thal et al. (1997) also following estimates for the number of *words that can be considered to be understood* by young children: 8-month-olds can understand about 25 words, 12-month-olds about 90 words and 16-month-olds about 200 words.

Bloom (2000) suggests that the *rate of learning new words* can be represented with following estimates: for ages 12–16 months 0.3 words per day, for ages 16–23 months 0.8 words per day, for ages 23–30 months 1.6 words per day, for ages from 30 months to 6 years 3.6 words per day, for ages 6–8 years 6.6 words per day and for ages 8–10 years 12.1 words per day. When continuing from produced vocabulary of 400 word for 2-year-olds previously identified based on Thal et al. (1997) these growing rates can be used to generate estimates that vocabulary is for a 3-year-old about 1350 words, for a 4-year-old about 2670 words and for a 5-year-old about 3990 words.

Nation and Waring (1997) estimated that a *five-year-old child* starting school has vocabulary of about 4000–5000 word families and every year a native speaker adds about 1000 word families to her vocabulary (corresponding to about 2.7 word families per day) until a university graduate has about 20000 word families in her vocabulary. On the other hand, D'Anna et al. (1991) estimated that a *college student* knows about 16785 different words. Nation (2006) reports that highly educated people studying advanced degrees through use of *non-native English language* have a receptive English vocabulary of approximately 8000–9000 word families. Lehr et al. (2004) conclude based on earlier research that students add about 2000–3500 distinct words every year to their *reading vocabulary* ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)) or alternatively 600–1200 new root word meanings in every year of elementary school ((Biemiller & Slonim 2001); (Anglin 1993)).

Lehr et al. (2004) emphasize earlier results that *school texts* from grade 3 through grade 9 contain about 88500 distinct word families (Nagy & Andersson 1984) but however that classroom intervention studies indicate that at school at most 8 to 10 new words can be taught effectively every week, meaning at most 400 new words per year (Stahl & Fairbanks 1986). Thus when contrasting these rates with estimated yearly adoption of 2000–3500 distinct words for students mentioned by Lehr et al. (2004), it can be estimated that a lot of remaining about 1600–3100 new words yearly or about 4–8 new words daily becomes adopted *outside direct teaching*. Similarly Kuhn and Stahl (1998) conclude based on earlier research that in school between kindergarten and 12th grade people are exposed to about 88700 word families (Nagy & Andersson 1984) and about 45000 of them are learned thus learning about 3000 new words per year ((Graves 1986); (White et al. 1990)) but that only about 300–400 words can be learned through direct instruction per year (Stahl 1991). These numbers seem to suggest that students can be expected to learn about 60 words per week and of which about 6–8 words through direct instruction, and that about 2600–2700 words per year become adopted outside direct teaching.

As already mentioned in Chapter 2, a power function formula $y=mx^b$ can be suggested to explain how much time in seconds (y) is needed to recognize precisely information that has been presented to a person after various amounts of exposures (x)

concerning this information so that parameters m and b can be defined to address a particular type of learning situation ((Marzano 2000) referring to Anderson (Anderson 1995)).

Baker et al. (1992) mention based on earlier research that especially at primary grades at school students learn 3000 new words per year thus corresponding about 8 words per day ((Baumann & Kameenui 1991); (Beck & McKeown 1991); (Graves 1986)). In addition, Baker et al. (1992) mention earlier research showing that in a collection of 5044 words *disadvantaged first graders* knew about 1800 words and *middle-class students* about 2700 words, and in a collection of 19050 words *disadvantaged first graders* knew about 2900 words and *middle-class first graders* about 5800 words (Graves et al. 1982). Furthermore, Baker et al. (1992) mention earlier research showing that in a collection of 19050 words *first graders* of two low socio-economic status schools knew about 2500 words and about 3500 words, and in a collection of 19050 words *first graders* of a middle socio-economic status school knew about 4800 words, and along grades 1–4 the students of two low socio-economic status schools learned about 3500 words per year and the students of a middle socio-economic status school learned about 5200 words per year (White et al. 1990).

Dupuy (1974) has estimated that there are 12300 basic words in English and that 7800 of these words are necessary for educational purposes for learners ranging from kindergarten to grade 12 thus requiring direct instruction of under 650 words per each year. Following suggestions of Dupuy a list of 8109 basic words was created by Becker et al. (1980). It has been estimated that starting from age of two years a child masters about 10 new words per day thus reaching a vocabulary of about 14000 words by age of six years (Clark 1993). In addition, it has been estimated that at grade 1 a child knows about 6000 words but recognizing them in print is so much harder that she recognizes in print only 3000 of them when she is at grade 4 (Chall 1987). Furthermore it has been estimated that an adult knows 25 percent more words that she uses in her speaking or writing (Crystal 1995). Also, it was found that in a sample of 9000 words of elementary school 72 percent of words had more than one meaning (Johnson et al. 1983).

Some estimates about properties of adoption of vocabulary that have been just discussed are shown in Table 11.1.

Table 11.1. Some estimates about properties of adoption of vocabulary.

<i>Parameter concerning adoption of vocabulary</i>	<i>Values found in previous research for this parameter</i>
vocabulary of a child	25 understood words (8-month-old child) (interpreted visually from graph in Thal et al. 1997); 90 understood words and 10 produced words (12-month-old child) (interpreted visually from graph in Thal et al. 1997); 200 understood words (16-month-old child) (interpreted visually from graph in Thal et al. 1997); 120 produced words (18-month-old child) (interpreted visually from graph in Thal et al. 1997); 400 produced words (24-month-old-child) (interpreted visually from graph in Thal et al. 1997); 560 produced words (30 month-old child) (interpreted visually from graph in Thal et al. 1997); 1350 word (3-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 2670 words (4-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 3990 words (5-year-old child) (estimated based on (Thal et al. 1997) and (Bloom 2000)); 4000–5000 word families (5-year-old child) (Nation & Waring 1997); 14000 words (6-year-old child) (Clark 1993); 6000 words that are known (child at grade 1) (Chall 1987); 3000 words that can be recognized in print (child at grade 4) (Chall 1987)
vocabulary of an adult	20000 word families (university graduate) (Nation & Waring 1997); 16785 words (college student) (D'anna et al. 1991); 45000 words (learned between kindergarten and grade 12) ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990))
sufficient vocabulary for a non-native adult	8000–9000 word families (Nation 2006)
encountered word families or words during school years	88500 word families encountered between grade 3 and grade 9 ((Lehr et al. 2004) referring to (Nagy & Andersson 1984)); 88700 word families encountered between kindergarten and grade 12 ((Kuhn & Stahl 1998) referring to (Nagy & Andersson 1984)); 12300 basic words of which 7800 words considered necessary for educational purposes from kindergarten to grade 12 (Dupuy 1974)
rate of learning new words	0.3 words per day (ages 12–16 months) (Bloom 2000); 0.8 words per day (ages 16–23 months) (Bloom 2000); 1.6 words per day (ages 23–30 months) (Bloom 2000); 3.6 words per day (ages from 30 months to 6 years) (Bloom 2000); 6.6 words per day (ages 6–8 years) (Bloom 2000); 12.1 words per day (age of 8–10 years) (Bloom 2000); about 10 words per day (starting form age of 2 years in early years) (Clark 1993); 1000 word families per year (from age of 5 years to age of an university graduate) (Nation & Waring1997); 2000–3500 words per year ((Lehr et al. 2004) referring to ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)); 600–1200 root word meanings per year ((Lehr et al. 2004) referring to ((Biemiller & Slonim 2001); (Anglin 1993)); 3000 words per year ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990)); 60 words per week (estimated based on (Kuhn & Stahl 1998)); 3000 words per year or 8 words per day (primary grades of school) ((Baker et al. 1992) referring to ((Baumann & Kameenui 1991); (Beck & McKeown 1991); (Graves 1986)); 3500 words per year (grades 1–4 in low socio-economy status school) and 5200 words per year (grades 1–4 in middle socio-economy status school) ((Baker et al. 1992) referring to (White et al. 1990))
new words learned through active teaching	at most 400 words per year or at most 8–10 new words per week ((Lehr et al. 2004) referring to (Stahl & Fairbanks 1986)); 300–400 words per year ((Kuhn & Stahl 1998) referring to (Stahl 1991)); 6–8 words per week (estimated based on (Kuhn & Stahl 1998)); under 650 words per each year (Dupuy 1974);
new words learned outside active teaching	1600–3100 words per year or 4–8 new words per day (estimated based on (Lehr et al. 2004)); 2600–2700 words per year (estimated based on (Kuhn & Stahl 1998))

11.2. Exposure required for learning

Nation and Waring (Nation & Waring 1997) conclude based on earlier research by Laufer (Laufer 1989) that about *95 percent coverage* is sufficient for reasonable comprehension of text meaning that density of unknown words in text can be at most be around one in every 20 encountered words. This coverage can be reached especially in favourable tailored textual contexts with 3000–5000 word families or just 2000–3000 word families ((Nation & Waring 1997) referring to (Laufer 1989)). Wozniak and Gorzelanczyk (Wozniak & Gorzelanczyk 1994) suggested a computational method to assist paired-associate learning by offering items to the learner so that inter-repetition intervals are optimized so that 5 percent of to-be-remembered items are not remembered at the moment of repetition. Hu and Nation (Hu & Nation 2000) experimentally found out that when reading fictional texts with strong chronological storyline without having access to dictionary or glossary (i.e. unassisted reading) most of the learners need to know *98 percent of the words* to get an adequate comprehension of the text. Thus the density of unknown words should not be greater than one in fifty words to maintain comprehension in reading.

Carver (Carver 1994) showed that when providing text passages of varied difficulty to students at grades 3–6 and graduate students, easy texts contained close to 0 percent unknown basic words, difficult texts 2 percent or more unknown basic words, and texts matched closely to learners ability about 1 percent unknown basic words. Based on British National Corpus, Nation (Nation 2006) has created fourteen consecutive *high-frequency lists* in sets of 1000 word families (word families having rank 1–1001, word families having rank 1001–2000, etc.) and with them found estimates for vocabulary sizes needed for sufficient comprehension in various forms of reading and listening.

Laufer and Ravenhorst-Kalakovski (Laufer & Ravenhorst-Kalakovski 2010) suggest based on empirical analysis that for independent reading comprehension second language learners should have a vocabulary of about 8000 words offering about 98 percent text coverage and for reading comprehension with some guidance and help they should have a vocabulary of about 4000–5000 words offering about 95 percent text coverage. Hsu (Hsu 2009) mentions earlier research (Carroll et al. 1971) that studied a collection of varied texts written for children in grades 3–9 containing 5 million words identifying that there were 86741 unique words, and furthermore it was found that 2000 most popular words can make a 80 percent coverage of word usage in longer texts and 5000 most popular words a 90 percent coverage, and correspondingly to have 95 percent coverage seems to require about 12000 words.

Based on the range of high-frequency words that follow original Zipf's law it appears that a *core vocabulary of English texts* can be considered to contain about 7873 words that have an exponential decay with a rate of about 30 words per year and a half-life of about 200 years (Gerlach & Altmann 2013). Lehr et al. (2004) also mention earlier findings that to convey actual content words about 50 percent of English text consists of only 107 *function words* like “are”, “that”, “a” and “to” (Zeno et al. 1995) and that it was identified that text in children's books can have twice as much infrequently used or rare words than even conversation among college graduates (Hayes

& Ahrens 1988). Language in the society is in a constant change and new concepts and meanings can be defined in almost unlimited way although meanwhile letting unused concepts and meanings to become obsolete.

Kilgarriff (Kilgarriff 1997) identified 6318 lemmatized words of British National Corpus that occur more than (or at least) 800 times. Chujo (Chujo 2004) identified 30297 different words and 14011 different lemmatized words based on a subset of about 86 million words of British National Corpus occurring at least 100 times. In addition, Chujo (Chujo 2004) found that to achieve a 95 percent coverage—suggested to be needed for reasonable comprehension—concerning the words of popular junior or senior high school *English-for-second-language* textbooks about 3000–3200 highest-ranking lemmatized words of British National Corpus were needed and respectively about 3800–4100 highest-ranking words to succeed in a proficiency test called Test of English for International Communication (TOEIC).

In the domain of learning English-for-second-language, Hsu (Hsu 2009) reports that intermediate college/university English-for-second-language textbooks typically have a vocabulary level of 4000–4500 most frequent word families of British National Corpus and that 2000 most frequent word families of the British National Corpus correspond to 11941 different words (word types including base forms, inflected forms and derivatives). In addition, Hsu reports that one typical college/university-English-for-second-language textbook can supply a student having a vocabulary size of 2000 word families with 162–2001 new word families (and 49–415 new academic word families based on set of 570 academic word families by Coxhead (Coxhead 2000)), with an estimate that the ratio of word types to word families is in the range from 1.54 to 2.18.

Deborah et al. (2004) found out that 2–4 years old children making inquiries about unfamiliar artifacts seemed to be looking for and being most satisfied with explanations that were given in the terms of the object's functions. Willingham and Price (Willingham & Price 2009) mention based on earlier research that a key word method called mnemonics is an effective way to learn unfamiliar low-frequency words by creating a memorable *mental visualization* (Simpson et al. 1987) emphasizing that the student herself should choose the images relating them to previous knowledge (McCarville 1993).

Some estimates about properties of exposure required for learning that have been just discussed are shown in Table 11.2.

Table 11.2. Some estimates about properties of exposure required for learning.

<i>Parameter concerning coverage of comprehension required for learning</i>	<i>Values found in previous research for this parameter</i>
percentage of known words in text required for sufficient comprehension	95 percent (Nation & Waring 1997); 95 percent (Wozniak & Gorzelanczyk 1994); 98 percent (Hu & Nation 2000) 95–98 percent (Laufer & Ravenhorst-Kalakovski 2010) 98–99 percent (Carver 1994)
unique words in a text collection of 5 million words	86741 words ((Hsu 2009) referring to (Carroll et al. 1971))
core vocabulary of English texts	7873 words (Gerlach & Altmann 2013)
size of vocabulary and its coverage of text	107 basic words cover about 50 percent ((Lehr et al. 2004) referring to (Zeno et al. 1995)); <i>based on text collection of 100 million words:</i> 6318 lemmatized words (occurring more than (or at least) 800 times) (Kilgarriff 1997); 14011 lemmatized words (occurring at least 100 times) (Chujo 2004) <i>based on text collection of 5 million words:</i> 2000 words cover about 80 percent ((Hsu 2009) referring to (Carroll et al. 1971)); 5000 words cover about 90 percent ((Hsu 2009) referring to (Carroll et al. 1971)); 12000 words cover about 95 percent ((Hsu 2009) referring to (Carroll et al. 1971)) <i>based on text collection with moderate size:</i> 3000–5000 word families or just 2000–3000 word families can cover 95 percent of suitable texts (Nation & Waring 1997) 4000–5000 words can cover 95 percent and 8000 words can cover 98 percent of text (Laufer & Ravenhorst-Kalakovski 2010) 3000–3200 highest-ranking lemmatized words of British National Corpus can cover 95 percent of high school text book (Chujo 2004); 3800–4100 highest-ranking words of British National Corpus can enable succeeding in proficiency test (Chujo 2004); a text book of college/university-English-for-second-language has a vocabulary level of 4000–4500 most frequent word families of British National Corpus (Hsu 2009) 2000 most frequent word families of British National Corpus correspond to 11941 different words and generally the proportion of words to word families is in range 1.54–2.18 (Hsu 2009) student's earlier vocabulary of 2000 word families can be increased with 162–2001 new word families by a text book of college/university-English-for-second-language (Hsu 2009)

11.3. Distributions of concepts

According to *Zipf's law* (Zipf 1935) pioneered by findings of Jean-Baptiste Estoup (Petruszewycz 1973), in large samples of natural language the frequency of any word $f(z)$ is inversely proportional to its rank z based on the high-frequency list of all words, i.e. $f(z) \sim z^{-\zeta}$ with scaling exponent ζ (Greek alphabet zeta) having value of about 1. When considering word frequency distribution with probability density function $P(f)$ it appears in a form proportional to $f^{-\alpha}$ where the value of α (Greek alphabet alpha) has two variants: for universally shared words with $f > 10^{-5}$ there is $\alpha \approx 1 + 1/\zeta \approx 2$ whereas for significantly less frequently universally used words with $f < 10^{-5}$ there is $\alpha \approx 1.7$ (these values should hold for example in English language but some languages such as Chinese, Russian and Hebrew seem to have lower values) (Petersen et al. 2012). The behavior of Zipf's law has been explained by Simon (Simon 1955) with a model according to which a document is expanded either with new word that has not yet occurred in the document with probability of β (Greek alphabet beta) or with an old

word with probability of $1 - \beta$, and this model is connected to the rank-frequency distribution of Zipf's law with a relation $\alpha = 1 + 1/(1 - \beta)$ (Simkin & Roychowdhury 2011).

In the notation concerning what we have just explained we have tried our best to synchronize usage of Greek letters in notation of (Simkin & Roychowdhury 2011) and (Petersen et al. 2012) so that they could correctly refer to same things without confusion.

According to *Heaps' law* (Heaps 1978), pioneered by Herdan's law (Herdan 1960), the number of distinct words in a document N_w is proportional to N_u^b , where N_u is the total number of words in a document and $b < 1$. When progressively excluding extremely rare words from large document, the value of b increases from 0.5 to 1 and especially when having words with frequencies of at least 1000 the value of b approaches 1 thus following relation $b = 1 / \zeta$ that has been suggested to connect Zipf's law and Heaps' law (Petersen et al. 2012).

It has been shown that the content of the Wikipedia follows approximately Zipf's law so that the exponent of probability density function $\alpha \approx 1.83$ and also Heaps' law so that the number of distinct words $w(n)$ grows sublinearly with n (Serrano et al. 2009). We think that since human communication in various forms of language seems to follow for example Zipf's law and Heaps' law it might be possible that also various forms of visualizations of educational material, possibly relying on exploration in conceptual networks, can have similar kind of naturally emerging models concerning optimally organized distributions and this kind of features could deserve to become exploited in development of new methods to support learning. It has been noted that there is increasing marginal return and decreasing marginal need for the addition of new words to language, and arrival of new words to a language seem to have growth-spurts of about 30–50 years after their introduction in written texts (Petersen et al. 2012).

In an analysis covering million domains having highest traffic of the Web, it was estimated that concerning hierarchical structures following power law distributions in *the Web* the alpha for *in-degree distribution* was 2.3 and the alpha for *out-degree distribution* was 2.4 (Ludueña et al. 2013). In an analysis covering over 400 million Web pages, it was estimated that a mean in-degree was 6.10 and a mean out-degree was 38.11 (Najork et al. 2007). Capocci et al. (2006) estimated, with an analysis covering 100 language versions of the Wikipedia, that both in-degree and out-degree distribution of the Wikipedia obey power law with $2 \leq \alpha \leq 2.2$. Zlatic et al. (2006) estimated with ten language versions of *the Wikipedia* that on average the alpha for *in-degree distribution* was 2.18 and for *out-degree distribution* 2.57, whereas for *English version* only the corresponding alpha values were 2.21 (in-degree) and 2.65 (out-degree).

In an analysis containing 650 000 Wikipedia articles having mean length of 2473 characters and median length of 1309 characters, Kams and Koolen (2009) computed that between Wikipedia articles both mean in-degree and mean out-degree had value 20.63, whereas median in-degree was 4 and median out-degree 12. In addition they found that both in-degree and out-degree of Wikipedia articles are good indicators of relevance of the article and difference between articles serving as hubs (based on outgoing links) and authorities (based on ingoing links) disappear, and that there was a

weak correlation between in-degree and out-degree as well as in-degree and article length whereas a strong correlation between out-degree and article length. It was shown in Wikipedia that distributions of both in-degree and PageRank values, used for evaluating popularity of web sites in network based on model of random walks, follow power laws with same exponent (Volkovich et al. 2007).

It has been shown that so called featured articles of the Wikipedia that have passed a specific evaluation process to meet requirements of high quality have substantially more editors involved than non-featured articles, and articles that have been edited by more editors are generally better than those edited by less editors but addition of editors requiring appropriate coordination techniques (Kittur & Kraut 2008). As already mentioned in Chapter 6 concerning articles that have been labeled in Wikipedia's own review process as "good articles" and "featured articles", Blumenstock (Blumenstock 2008) showed that the *featured articles* can be recognized correctly with the accuracy of 96 percent using a simple heuristic that classifies articles with more than 2000 words as "featured" and articles with fewer than 2000 words as "random", and that Thomas and Sheth (Thomas & Sheth 2007) showed that when comparing labelled *good articles* to other non-stub articles having at least 50 revision milestones they found no statistically significant difference in convergence to a semantically stable state.

On the other hand, Braun and Schmidt (Braun & Schmidt 2007) estimated based on sample of 68854 articles of German Wikipedia the number of words per article and the number of unique internal links per article in respect to four quality classes of article including stub articles, normal articles, labeled "good articles" and labeled "featured articles". They found out that there were for stub articles on average 43 words (median value 4), for normal article on average 1196 words (median value 753), for labeled "good article" on average 5386 words (median value 4580) and for labeled "featured article" on average 6689 words (median value 5952). They also found out that there were for stub articles on average 6 internal links (median value 1), for normal article on average 75 internal links (median value 55), for labeled "good article" on average 212 internal links (median value 170) and for labeled "featured article" on average 240 internal links (median value 213).

From different language versions it was estimated that in the growth of the Wikipedia the relation between the number of directed links L and the number of nodes N (i.e. nodes corresponding to Wikipedia articles) in the Wikipedia obeys approximately $L = N^{1.4}$ (Zlatic et al. 2006). Spinellis and Louridas ((Spinellis & Louridas 2008a); (Spinellis & Louridas 2008b)) found out that in the Wikipedia the ratio between incomplete articles (either stubs or being present only as a link to non-existing entry) and complete articles was about 1.35 in January 2008. They also found that having a reference to a non-existent entry is positively correlated with addition of a new article, and when observed in monthly time windows the article was created most often in the month the first reference was made, and this article was created by another person than the person adding the first reference in 97 percent of cases. With a study covering about 5.7 million article revisions and an approximated number of 51 billion views Priedhorsky et al. (2007) estimated that about 5 percent of article revisions are damaged and a typical view encounters damage with probability of about 0.0037.

According to usage patterns of articles in the English edition of the Wikipedia there was a ratio of 620 reading operations per one saving operation (Reinoso et al. 2009).

Some estimates about properties of distributions of concepts that have been just discussed are shown in Table 11.3.

Table 11.3. Some estimates about properties of distributions of concepts.

<i>Parameter concerning evolution of textual content and linkage</i>	<i>Values found in previous research for this parameter</i>
length of Wikipedia article	2473 characters (mean length) and 1309 characters (median length) (Kamps & Koolen 2009); for stub articles on average 43 words (median value 4) (Braun & Schmidt 2007); for normal article on average 1196 words (median value 753) (Braun & Schmidt 2007); for labeled "good article" on average 5386 words (median value 4580) (Braun & Schmidt 2007); for labeled "featured article" on average 6689 words (median value 5952) (Braun & Schmidt 2007)
probability density function of word frequency distribution P(f) (Zipf's law)	<i>for large texts:</i> proportional to f^{-2} (Petersen et al. 2012) <i>for large texts with rare words:</i> proportional to $f^{-1.7}$ (Petersen et al. 2012) <i>for words in the wikipedia:</i> proportional to $f^{-1.83}$ (Serrano et al. 2009)
number of distinct words w(n) in texts of n words (Heaps' law)	<i>for large texts:</i> proportional to n^{-1} (Petersen et al. 2012) <i>for large texts with rare words:</i> proportional to $n^{-0.5}$ (Petersen et al. 2012) <i>for text in the wikipedia:</i> sublinear growth with n (Serrano et al. 2009)
alpha for power law distribution of in-degree and out-degree	<i>in the Web:</i> 2.3 (in-degree) and 2.4 (out-degree) (Ludueña et al. 2013); <i>in the Wikipedia (100 language versions):</i> between 2 and 2.2 (in-degree) and between 2 and 2.2 (out-degree) (Capocci et al. 2006); <i>in the Wikipedia (10 language versions):</i> 2.18 (in-degree) and 2.57 (out-degree) (Zlatic et al. 2006); <i>in the Wikipedia (English version):</i> 2.21 (in-degree) and 2.65 (out-degree) (Zlatic et al. 2006)
values about in-degree and out-degree	<i>in the Web:</i> 6.10 (mean in-degree) and 38.11 (mean out-degree) (Najork et al. 2007) <i>in the Wikipedia:</i> 20.63 (mean in-degree) and 20.63 (mean out-degree) (Kamps & Koolen 2009); 4 (median in-degree) and 12 (median out-degree) (Kamps & Koolen 2009) for stub articles on average 6 internal links (median value 1) (Braun & Schmidt 2007); for normal article on average 75 internal links (median value 55) (Braun & Schmidt 2007); for labeled "good article" on average 212 internal links (median value 170) (Braun & Schmidt 2007); for labeled "featured article" on average 240 internal links (median value 213) (Braun & Schmidt 2007)
relation between the number of directed links L and the number of articles N in the Wikipedia	approximately $L=N^{1.4}$ (Zlatic et al. 2006)
features about creation and revisions of Wikipedia articles	the ratio between incomplete articles and complete articles is about 1.35 (Spinellis & Louridas 2008a); a new article was created by another person than the person adding the first reference in 97 percent of cases and most often in timeframe of one month (Spinellis & Louridas 2008a); about 5 percent of article revisions are damaged and a typical view encounters damage with probability of about 0.0037 (Priedhorsky et al. 2007); for articles there was 620 reading operations per one saving operation (Reinoso et al. 2009)

11.4. Perspectives of conceptual structures

An approach for building fertile conceptual network for learning is to establish linking based on relatedness of features based on various *human ratings*. In this respect interesting is for example early work of Friendly et al. (1982) who defined norms for imagery, concreteness, orthographic variables and grammatical usage for a set of 1080 common words of English belonging to Toronto Word Pool used in learning studies. More recently, in similar fashion for example emotional norms have been defined for a set of 600 words (Syssau & Monnier 2009). Samuels et al. (2003) showed experimentally that feedback concerning independent learning had significant positive effect on student achievement. Baker et al. (1992) mention earlier research (Carey 1978) that has suggested that adoption of vocabulary happens with both a *cursorly fast mapping* based on even just one exposure to a word and a *deeper extended mapping* requiring typically multiple exposures to word and that a school-aged child can be concurrently processing even 1600 word mapping at various stages of mapping and if a child learns 8 new words per day most of them are learned only cursorily.

Gardner (Gardner 2008) claims that in children's reading collections there is a great difference in vocabularies of *narrative texts* and *expository texts* and although expository texts have not been considered friendly to incidental word learning from context (Anderson 1996) expository texts are suggested to provide useful conditions for topic-related theme-specific vocabulary recycling especially with a tight theme. According to Gardner, tighter themes in expository texts offered more topic-related vocabulary recycling than looser themes whereas tightness of themes had little or no impact on topic-related vocabulary recycling among narrative texts, and narratives written by the same author offered more topic-related vocabulary recycling than narratives written by multiple authors whereas number of authors had no observable impact on topic-related vocabulary recycling among expository texts. Gentner and Boroditsky (Gentner & Boroditsky 2009) mention based on earlier research that in children's early word learning there is a *noun dominance* in both language production ((Gentner 1982); (Huttenlocher 1974); (Nelson 1973)) and comprehension (Goldin-Meadow et al. 1976) motivated by suggestions that concrete objects and entities are easier to individuate and label than relational constellations and that noun meanings vary crosslinguistically less than verb meanings.

Emotional aspects probably affect cognitive processes and *anxiety* seems to have effect on person's ability to generate analogies that establish mappings between entities. Persons having a state of anxiety (i.e. this term does not refer to trait of anxiety) generated to a given base problem analogies that were mainly close analogies and belonging to one domain whereas persons having non-anxious state generated analogies with remote domains and belonging to two or three domains (Feldman & Kokinov 2009). Findings of Tohill and Holyoak (Tohill & Holyoak 2000) suggest that person having state of anxiety prefer more superficial attributive mapping instead of relational mapping. On the other hand, findings of Feldman et al. (2010) suggest that persons having anxious state prefer more relational mapping instead of superficial mapping and they motivate these findings by mentioning based on previous research that in three

attentional neural networks distinguished by Posner et al. (2007) state of anxiety has been shown to enhance working of alerting network and orienting network but not significantly executing network whereas trait of anxiety (i.e. this term does not refer to state of anxiety) did not have effect on alerting network and orienting network but seriously diminished executive control (Pacheco-Unguetti et al. 2010).

Johnson (2000) considers vocabulary as an important tool to understand the world and to be understood by others and suggests using *thesaurus* to develop language ability. Johnson mentions influential early work of Roget's thesaurus (Roget 1852) aiming to organize general human knowledge with a hierarchical system containing six main categories defined as abstract relations, space, the material world, the intellect, volition, and sentient and moral powers, that were further divided into 1000 semantic subcategories. Johnson also mentions an illustrated children's thesaurus Words to Use (Drysdale 1974) having six main categories defined as The World We Live In, Living Things, Being Alive, How We View the World, Living Together, and Words for Sentence Building that are divided hierarchically further into subcategories to represent words, and publication A Cluster Approach to Elementary Vocabulary Instruction (Marzano & Marzano 1988) that presents a semantical categorization with a three-level *clustering hierarchy* for 7230 words that are commonly used in elementary school texts so that words in clusters at the lowest level are supposed to have the highest semantic relatedness even if they are not required to be synonyms.

Marzano and Marzano (1988) explain that their clustering hierarchy is based on about 7000 words they selected from three resources ((Harris & Jacobson 1972); (Carroll et al. 1971); (Dahl 1979)), and which they iteratively categorized following review feedback given by 60 elementary school teachers until teachers identified less than 5 words in 1000 words being miscategorized. The clustering hierarchy contains on the highest level 61 *superclusters* of words and superclusters have together 430 clusters on a lower level and then these clusters have 1500 miniclusters on the lowest level. Listing of clustering hierarchy is supplied with suggestions about at which grade level each word could be introduced to a learner relying on grade levels identified by Harris and Jacobson (1972) based on analysis of elementary school reading series or alternatively estimates by the list of Thorndike and Lorge (1943) that were adjusted based on review feedback from 60 teachers assisting the researchers. Table 11.4 shows topics of all 61 superclusters in decreasing order of the number of words they include.

Table 11.4. A list of topics of all 61 superclusters of clustering hierarchy introduced by Marzano and Marzano (Marzano & Marzano 1988) in decreasing order of the number of words they include.

<i>Name of supercluster of words</i>	<i>Number of words</i>		<i>Name of supercluster of words (continued)</i>	<i>Number of words</i>
1. Occupations	364		32. Shapes/dimensions	90
2. Types of motion	321		33. Destructive/helpful actions	87
3. Size/quantity	310		34. Sports/recreation	80
4. Animals	289		35. Language (names for different aspects of written and oral language)	80
5. Feelings/emotions	282		36. Ownership/possession	68
6. Foods/meals (names for various food types and situations involving eating)	263		37. Disease/health	68
7. Time (names for various points and periods of time and words indicating various time relationships between ideas)	251		38. Light (names for light/darkness and things associated with them)	68
8. Machines/engines/tools	244		39. Causality	59
9. Types of people (names for various types or categories of people that are not job related)	237		40. Weather	55
10. Communication (names for various types of communications and actions involving communications)	235		41. Cleanliness/uncleanliness	53
11. Transportation	205		42. Popularity/knownness	52
12. Mental actions/thinking	193		43. Physical traits of people	51
13. Nonemotional traits (general, nonphysical traits of people)	175		44. Touching/grabbing actions	50
14. Location/direction	172		45. Pronouns (personal, possessive, relative, interrogative, indefinite)	50
15. Literature/writing	171		46. Contractions	49
16. Water/liquids (names for different types of liquids and bodies of water)	164		47. Entertainment/the arts	48
17. Clothing	161		48. Actions involving the legs	46
18. Places where people live/dwell	154		49. Mathematics (names for various branches of mathematics, operations and quantities)	46
19. Noises/sounds	143		50. Auxiliary/helping verbs (forms of to be, modals primary and semiauxiliaries)	46
20. Land/terrain (names for general categories of land or terrain)	142		51. Events (names for general and specific types of events)	44
21. Dwellings/shelters (names for various types of dwellings/places of business)	141		52. Temperature/fire	40
22. Materials (names for materials used to make things)	140		53. Images/perceptions	39
23. The human body	128		54. Life/survival	38
24. Vegetation	116		55. Conformity/complexity	34
25. Groups (general names for groups and organizations)	116		56. Difficulty/danger	30
26. Value/correctness	108		57. Texture/durability	30
27. Similarity/dissimilarity (names indicating how similar or different things are and the sameness or difference between ideas)	108		58. Color	29
28. Money/finance	102		59. Chemicals	28
29. Soil/metal/rock	102		60. Facial expressions/actions	21
30. Rooms/furnishings/parts of dwellings	97		61. Electricity/particles of matter	21
31. Attitudinals (words indicating the speaker/writer's attitude about what is being said or written)	96			
<i>(the listing continues on the fourth column of this table)</i>				

With an aim to emphasize primary components of narrative texts relying on findings of Stein and Glenn (1979) and Whaley (1981), 61 superclusters belonging to clustering hierarchy of Marzano and Marzano (1988) were grouped by Hiebert to form 13 *vocabulary megaclusters* (Hiebert 2011). Table 11.5 shows topics of all 13 vocabulary megaclusters of Hiebert (2011) formed by grouping 61 superclusters of Marzano and Marzano (1988) and indicates superclusters belonging to each vocabulary megacluster.

Table 11.5. A list showing topics of all 13 vocabulary megaclusters of Hiebert (Hiebert 2011) formed by grouping 61 superclusters of Marzano and Marzano (Marzano & Marzano 1988). The numbers in second column indicate the superclusters numbered in Table 11.4 that belong to each megacluster, some of the superclusters have been excluded (including pronouns, contractions and auxiliary/helpful verbs) and some other superclusters have been renamed or merged, as explained by Hiebert (Hiebert 2011).

We expect that Hiebert means Images/perceptions when referring to Senses/perceptions, Groups when referring to Types of groups, Rooms/furnishing/parts of dwellings when referring to Rooms/furnishing, Disease/health when referring to Health/disease, Foods/meals when referring to Foods and Electricity/particles of matter when referring to Electricity, and Motion when referring to Types of motion (indicated with an asterisk (*) in this table).

Name of vocabulary megacluster	Superclusters belonging to current vocabulary megacluster (numbers refer to Table 11.4)
I. Emotions & attitudes	5, 31
II. Communications	10, 19, 12, 53*, 60
III. Traits of character	13, 43
IV. Social relationships	36, 42, 54, 55
V. Characters	1, 9, 25*
VI. Action & motion	2*, 33, 44, 48
VII. Human body	17, 23, 37
VIII. Features of events/things/people	26, 27, 39, 41, 56
IX. Places/events	18, 21, 30*, 51
X. Physical attributes of things/events/experience	3, 7, 14, 32, 57, 58
XI. Natural environment	4, 6*, 16, 20, 24, 29, 38, 40, 49, 52, 59, 61*
XII. Machines	8, 11, 22
XIII. Social systems	15, 28, 34, 35, 47

11.5. Spacing and repetition patterns

In the frame of cognitive psychology, it has been suggested that learning can be seen to happen both explicitly and implicitly. In vocabulary learning, *explicit learning* can be considered conscious searching, building and testing of hypothesis and assimilation of rules following explicit instruction by studying decontextualized lexis, using dictionaries and interfering from context, whereas *implicit learning* can be considered automatic abstraction of structural knowledge through instances of experience by engaging students in meaning-focused reading (Hunt & Beglar 2005).

Mazur (Mazur 2003) experimentally found indication that *spacing* benefits abstract learning when task is mastered initially and even if the theoretical explanations for spacing effect are missing he lists based on previous research (Dempster 1988) three suggested explanations: voluntary attention hypothesis explaining that individuals choose to pay more attention to spaced than non-spaced (massed) repetitions, encoded variability explaining that if information is presented in different contexts there can be more retrieval routes in memory, and rehearsal hypothesis explaining that the ability to recall benefits from having rehearsal time immediately after presentation of information.

Vlach and Sandhofer (Vlach & Sandhofer 2012) experimentally showed that by spacing lessons in time promoted children's ability for simple and complex generalization of science concepts that was measured one week after the last lesson. Baumann (Baumann 2005) mentions based on earlier research that, largely agreeing with Mezynski (Mezynski 1983) and Graves (Graves 1986), a meta-analysis of Stahl and Fairbanks (Stahl & Fairbanks 1986) found that reading comprehension was promoted when vocabulary instruction contained deeper processing, multiple encounters and combination of definitional and contextual information whereas comprehension was not enhanced when simply providing definitions, having one or two encounters with words, or using drill-and-practice method exclusively.

Bolger et al. (2008) experimentally found that exposure to *variable context* resulted in better learning of abstract meaning than similar exposure to a single context and that definitions conveyed this knowledge more effectively than context alone. Scott and Nagy (1997) found out that students seem to experience fundamental difficulties when trying to use information provided in definitions concerning syntactic or semantic categories of unfamiliar words. Dellarosa and Bourne (1985) provided sentences repeatedly in the same form and in a form that maintained meaning with somewhat different words, and they found out that in a reproduction task learners receiving *varied form* managed better, and similar advantage of diversity was gained when providing sentences to learners by varied speakers. Lehr et al. (2004) mention previous research of Cunningham and Stanovich (1991) that found that the vocabulary knowledge for students in grades 4, 5 and 6 gets significant contribution from *reading volume* (amount of time spent reading).

McKeown and Beck (2011) mention based on earlier work that McKeown et al. (1985) compared instruction relying on active processing and practicing of definitions, both with either twelve or four encounters of words, finding that only instruction engaging active processing and twelve encounters showed comprehension effects. Nation (1999) suggested that about ten repetitions is a desirable number of encounters with a word in reading to ensure learning it. Bloom and Shuell (1981) mention previous research of Reynolds and Glaser (1964) finding that retention of learning material can be improved by spaced review whereas simple repetition has only limited influence on retention. *Repeated retrieval* of information has been shown as a key factor to long-term retention (Karpicke & Roediger III 2007). One of the earliest known studies in this field is work by Ebbinghaus (1885) showing the gradually decreasing recalling rate of nonsense syllables as a function of time. Bahrack et al. (1993) showed that the level of retention could remain same with smaller number of repetitions if the spacing was increased, as was the case with 13 repetitions 56 days apart versus 26 repetitions 14 days apart.

Dempster (1988) suggested that spacing effect should be more actively applied in educational practices since it seems to have a lot of unexploited potential and argues that despite many early promising findings there seems to be discontinuities in research and implementation of its results. Sharifian (2002) mentions previous findings of Dempster (1987) showing that when the learners were exposed to 38 uncommon English words accompanied with their definitions, the recall was better if a sequence of

38 words was shown three times thus separating re-exposures with 37 words rather than showing each word three times consecutively. Need for more analysis has been suggested about how spacing effect is related to a learner's developmental phase, paraphrasing (i.e. rephrasing a thing in different words) and how testing reinforces learning (Dempster 1989).

Kahana and Howard (2005) showed that recall of repeated items was better for spaced lists than massed lists and better for widely spaced repetition than moderately spaced repetitions and they suggest the advantage being motivated by contextual variability enabling increased retrieval cues and associations. In meta-analysis of 317 experiments, Cepeda et al. (2006) concluded that when compared to non-spaced learning, *spaced learning of items* consistently showed benefits regardless of retention interval, and learning benefits increased as time lags increased between learning presentations. In addition they concluded that interstudy intervals that produced maximal retention increased as retention interval increased.

Nation and Wang (1999) analyzed series of 42 textbooks called graded readers that aim to gradually expand learner's vocabulary by introducing cumulatively 2410 new words at six consecutive complexity levels. Each book contained 6512–28360 words and text in seven books of each level had new words introduced at current level so that after level 1 it gradually decreases from 9.0 percent (level 2) to 1.9 percent (level 6). At five last levels, each new word introduced at current level represented coverage of text decreasing from 0.031 percent (level 2) to 0.005 percent (level 6). To reach ten repetitions assumed to ensure learning each new word ((Nation & Wang 1999) referring to (Nation 1999)), it was estimated that a learner should read 5–9 books at each level, corresponding to reading at each level a text having a total length ranging from 32258 words (level 2) to 200000 words (level 6). Dividing these values by the number of repetitions (ten), it thus follows that while reading the text, *the number of other words between two encounters* of a same word ranges on average from 3226 words (level 2) to 20000 words (level 6). With an assumption that weakening memory requires next encounter to be spaced at most by a week, a suggestion was then formulated that a learner should read each week at least these same amounts of text ranging from 3226 words per week (level 2) to 20000 words per week (level 6).

Hunt and Beglar (2005) mention based on earlier research that learning effectiveness benefits from *combined distributed adoption and retrieval* of knowledge at the longest delay that still maintains correct recall (Landauer & Bjork 1978), for example gradually increasing delay for repeated retrieval, with a delay of 30 days suggested to maximize retention ((Bairick 1984); (Bairick & Phelps 1987)). It has remained open question whether *gradually expanding spacing* of retrieval can outperform evenly spaced retrieval in learning but it has been suggested that in practice increasing retention intervals is likely to be reinforcing for the learner and can be applied without a need to identify the optimal evenly spaced schedule in advance (Balota et al. 2007).

Based on previous research, Thalheimer (2006) concludes that successful experiments have had three or more repetitions and that longer spacing of repetition supports longer retention periods. He suggests that an *ideal spacing interval* should be

about equal to retention interval thus corresponding to the time the learner is expected to remember information before it is applied. He suggests that consistent and expanding spacing should be equally fertile if the learning relies on tasks in which learner simply perceives prompted presentation of information or tasks in which retrieval relies on giving feedback about learner responses to prompted cues. However, expanding spacing can outperform consistent spacing if learners do not get feedback on their retrievals. He lists three often suggested reasons for advantage of spaced repetition which include getting memory encoding variability due to varying learning contexts, getting deeper processing in memory than with massed repetition and that identifying failures in retention motivates more intense processing.

Research findings about how *neural activity* proceeds and spreads in living neural systems on cellular level can possibly offer some rough guidelines for defining and adjusting suitable spacing for learning activities in educational work. Signals proceed from one neuron to next neuron through synapses that connect first neuron's axon to next neuron's dendrite. The synapse becomes stimulated as axon side releases serotonin and the dendrite side detects it. When stimulated by serotonin above a threshold, a small voltage potential is created called early *long-term potentiation* (LTP) which can last from one to three hours. An influential early mathematical model explaining initiation and propagation of action potentials in neurons is *Hodgkin-Huxley model* that has given ground for many later adaptations (Hodgkin & Huxley 1952). According to *Hebbian learning theory* associative learning relies on simultaneous activation of neural cells that increases synaptic strengths between them (Doidge 2007). Memory traces are stabilized by synaptic consolidation within minutes to hours of learning and by system consolidation within weeks, months or even years.

In *synaptic consolidation*, it has been considered that synaptic plasticity and synaptic strength are important for memory formation and rely largely on long-term potentiation that is prolonged enhanced signal transmission on cellular level between neurons. This is based on complex chemical chain reactions of stimulating and inhibiting neurotransmitter chemicals and proteins produced by genes activated in the nucleus of the cell ((Lynch 2004); (Whitlock et al. 2006)).

In *system consolidation*, to enable long-term memory formation memories are expected to be stored first in the hippocampal region of brain and then transferred to neo-cortex region or alternatively memories are always stored in neo-cortex region but are bound by hippocampal region (Nadel et al. 2003). So called *standard model* assumes that hippocampal complex works first as an index (H-trace) enabling various parts of memory stored in cortical sites (C-traces) to be reactivated/retrieved together but along time these sites become linked directly and the index becomes recycled. Here the suggested working principle remains same for both episodic and semantic memory. Standard model is challenged by *multiple trace theory* (Nadel & Moscovitch 1997) which assumes that hippocampal constantly represents episodic contextual indexes for cortical sites and since each reactivation/retrieval takes place in different context the traces become updated. Now there is a need to consider episodic and semantic memory separately.

Due to ethical reasons research of processes of human brain has been largely based on animals having neural systems resembling sufficiently human neural systems or by studying human patients having exceptional physiology inherently or due to a trauma. Harvey and Svoboda (2007) showed with mice and rats that when a spine of synapse is stimulated to action potential also surrounding spines in distance of 10 micrometers are more sensitive for stimulus for about 10 minutes. Kandel (2001) showed that stimulation of synapses of a marine snail can be successfully triggered by 4–5 spaced puffs of serotonin leading to activation of genes establishing *long-term memory*. Fields (2005) showed that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes. With functional magnetic resonance imaging Tambini et al. (2010) showed that during a rest following an associative encoding task the hippocampal-cortical correlations predicted later associative memory.

All these findings seem to indicate that there are fundamental physiological properties of brain that govern under what sequential conditions learning can happen and be efficient. Apparently there is a great variety of individual differences of neurological characteristics but some general guidelines can be suggested based on the findings. Thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures. Marine snail exposed to four brief trains for four days could generate memories that lasted weeks (Kandel 2001).

Some estimates about properties of spacing and repetition patterns to support learning that have been just discussed are shown in Table 11.6.

Table 11.6. Some estimates about properties of spacing and repetition patterns.

An aspect of spacing and repetition to be considered	Motivating arguments based on previous research for this aspect
advantage from spaced exposures and multiple exposures	spacing exposures support learning if task mastered initially (Mazur 2003); spacing lessons outperformed non-spacing lessons (Vlach & Sandhofer 2012); multiple exposures outperform one or two exposures ((Baumann 2005) referring to ((Stahl & Fairbanks 1986); (Mezynski 1983); (Graves 1986))); twelve exposures outperform four exposures ((McKeown & Beck 2011) referring to (McKeown et al. 1985)); 10 exposures needed to ensure learning (Nation 1999)
advantage from spaced retentions	repeated retrievals support significantly and repeated exposures only transiently (Reynolds & Glaser 1964); multiple retrievals as a key factor (Karpicke & Roediger III 2007); while maintaining retention level, number of retentions can be decreased if spacing of retentions is increased (Bahrick et al. 1993)
advantage from making spacing wider	3 exposures spaced with 259 seconds outperformed 3 consecutive exposures (Dempster 1987); spaced lists outperformed massed lists and wider spacing outperformed tighter spacing (Kahana & Howard 2005)
some conclusions of meta-analysis of 317 experiments about spaced learning	spacing exposures outperformed non-spaced exposures and wider spacing of exposures outperformed tighter spacing of exposures (Cepeda et al. 2006); spacing of exposures that produced maximal retention increased as spacing of retentions increased (Cepeda et al. 2006)
reaching limits with gradually expanding spacing	exposures should be spaced at most by a week (Nation & Wang 1999); exposures and retention with the longest delay that still maintains recall ((Hunt & Beglar 2005) referring to (Landauer & Bjork 1978)); gradually expanding retention delay until 30-day delay ((Hunt & Beglar 2005) referring to ((Bahrick 1984); (Bahrick & Phelps 1987))); expanding spacing of retention is considered reinforcing and without need to identify optimal evenly spaced intervals in advance (Balota et al. 2007)
tailoring spacing for current situation	3 or more repetitions needed to ensure learning (Thalheimer 2006); around 10 repetitions desirable to ensure learning a new word ((Nation & Wang 1999) referring to (Nation 1999)); longer spacing of exposures supports longer spacing of retention (Thalheimer 2006); spacing of exposures and spacing of retentions should be about equal and match the time required for remembering (Thalheimer 2006); expanding spacing may outperform evenly spaced intervals if learners do not get feedback on their retrievals (Thalheimer 2006)
features of neural systems in learning	stimulus of spine of synapse makes surrounding spines in distance of 10 micrometers more sensitive for about 10 minutes (Harvey & Svoboda 2007) stimulation of synapses can be triggered by 4–5 spaced puffs of serotonin thus activating genes establishing long-term memory (Kandel 2001) at least three action potentials at least 10 minutes apart can activate a gene for long-term memory formation in a synapse and activated gene can produce required proteins for about 30 minutes (Fields 2005). marine snail exposed to four brief trains for four days could generate memories that lasted weeks (Kandel 2001)

11.6. Manageable amounts of information

Empirical findings show that increasing physiological and mental arousal is positively correlated with person’s increasing performance up to somewhat optimal peak level but if physiological and mental arousal still further increase the performance declines and this relationship referred to as *Yerkes-Dodson law* has been connected to effects of stress hormones ((Yerkes & Dodson 1908); (Diamond, D. et al. 2007)).

To better understand cognitive processes of students belonging to any age, useful insight can be gained by analyzing developments of *cognitive processes of infants* who

are still in early stages of learning. Wojcik (2013) mentions based on previous research that maximum *time of remembering* for infants who are 2–18 months old increases monotonically so that 2-month-olds can retain a memory after one day, 3-month-olds after one week, 6-month-old after two weeks, 9-month-olds after six weeks, 12-month-olds after eight weeks, 15-month-olds after ten weeks and 18-month-olds after thirteen weeks ((Hartshorn et al. 1998); (Vander Linde et al. 1985); (Greco et al. 1990); (Hill et al. 1988); (Hartshorn & Rovee-Collier 1997)).

In addition, Wojcik (2013) mentions based on previous research that older infants need shorter *exposure times* to learn given stimuli than younger infants so that 2-month-olds need 3–6 minutes of exposure, 3-month-olds need 2–3 minutes exposure and 6-month-olds need 1 minute exposure ((Greco et al. 1986); (Greco et al. 1990); (Hill et al. 1988)). Furthermore, Wojcik (2013) mentions based on previous research that for infants the maximum *retention time* is the same for both reactivated memory and original memory ((Rovee-Collier et al. 1980); (Hildreth & Rovee-Collier 2002); (Hildreth et al. 2003)), and 2-month-olds can after two training session separated by one day followed by six spaced reminder sessions 3 weeks apart still show signs of retention (Rovee-Collier et al. 1999).

Based on over 32000 hours of data from 2682 recordings of LENA Natural Language study carried out with 329 participants in first phase and 80 participants in second phase produced measures about *language development of infants*. This study showed that on average children in ages of 2–30 months heard from all adults about 12815 words per day and this consisted of about 3184 words per day coming from male adult and about 9631 words per day coming from female adult and female child hears about 5.8 percent more words than male child, and for a typical family with a 24-month-old child there were on average 520 *conversational turns* per day (Gilkerson & Richards 2009). Based on recorded speech samples of 396 persons in age range of 17–29 years, it was estimated that men spoke 15669 words and women 16215 words per day (Mehl et al. 2007).

In addition LENA Natural Language study (Gilkerson & Richards 2009) showed that when children grow older those children that have more talkative parents generate higher number of daily child *vocalizations* than those children that have less talkative parents. This difference in average daily child vocalizations for children having parents that belong to the lowest 20th percentile in contrast with the highest 20th percentile in respect to adult word count seems to define following estimated value ranges that we visually interpreted from a graph from LENA Natural Language study so that lower end of range represent having parents that belong to the lowest 20th percentile and higher end of range represents having parents that belong to the highest 20th percentile in respect to adult word count: 2-month-olds generate about 550 daily child vocalizations (about same value for children of both talkative and untalkative parents), 6-month-olds about 800–1000 daily child vocalizations, 12-month-olds about 1000–1500 daily child vocalizations, 18-month-olds about 1200–1800 daily child vocalizations, 24-month-olds about 1300–2200 daily child vocalizations, 36-month-olds about 1600–2700 daily child vocalizations and 48-month-olds about 1700–2700 daily child vocalizations (Gilkerson & Richards 2009).

Juster et al. (2004) measured *time use for students* of ages of 6–17 years living in a family having computer with internet measured in years 2002–2003 based on data about 2908 children. Time use in school per week was 33 h 54 min for 6–8-year-olds, 32 h 44 min for 9–11-year-olds, 33 h 15 min for 12–14-year-olds and 30 h 21 min for 15–17-year-olds (Juster et al. 2004). Time use in studying (excluding time used in school) per week was 2 h 26 min for 6–8-year-olds, 3 h 31 min for 9–11-year-olds, 5 h 3 min for 12–14-year-olds and 5 h 20 min for 15–17-year-olds (Juster et al. 2004). Time use in reading per week was 1 h 28 min for 6–8-year-olds, 1 h 42 min for 9–11-year-olds, 1 h 42 min for 12–14-year-olds and 0 h 58 min for 15–17-year-olds (Juster et al. 2004). Time use in being read to per week was 0 h 12 min for 6–8-year-olds, 0 h 6 min for 9–11-year-olds, 0 h 3 min for 12–14-year-olds and 0 h 0 min for 15–17-year-olds (Juster et al. 2004). Time use in computer activities per week was 1 h 8 min for 6–8-year-olds, 1 h 41 min for 9–11-year-olds, 4 h 5 min for 12–14-year-olds and 6 h 6 min for 15–17-year-olds (Juster et al. 2004).

It has been estimated that time required to adopt professional *proficiency in a foreign language* by a native English speaker ranges from 23–24 weeks or 575–600 class hours (for languages that are closely related to English, for example French) to 88 weeks or 2200 class hours (for languages which are exceptionally difficult, for example Arabic) (Sanatullova-Allison 2009). Related to just described estimates please note that Subchapter 12.2 discusses about requirements suggested for reaching six progressive language ability levels of Common European Framework of Reference.

We think that above mentioned results of previous research motivate creating such educational content and its adaptive representation techniques that could enable a learner to become optimally sequentially exposed to new knowledge and its retention with sufficient spacing and repetition. The optimal timing schemes could be experimentally tailored for each learner to address her personal characteristics, age and level of knowledge as well as for each learning topic. Pavlik and Anderson (2008) showed that an algorithm tailored to dynamically increase and decrease temporal spacing of items provided an optimized condition that improved recall and recall latency when compared to other conditions, thus aiming to both increasing long-term recall and minimizing failure-related time cost of practice. Mettler et al. (2011) suggested that repetition intervals should be defined as an inverse function of response time and an experimental group learning basic multiplication facts with this method outperformed a group attending traditional instruction.

Some estimates about properties of manageable amount of information in learning that have been just discussed are shown in Table 11.7.

Table 11.7. Some estimates about properties of manageable amounts of information.

<i>An aspect of manageable amount of information to be considered</i>	<i>Values found in previous research concerning this aspect</i>
possible duration of time to still retain a memory for infants	for 2-month-olds after 1 day ((Wojcik 2013) referring to (Vander Linde et al. 1985)); for 3-month-olds after 1 week ((Wojcik 2013) referring to (Greco et al. 1990)); for 6-month-olds after 2 weeks ((Wojcik 2013) referring to ((Hill et al. 1988); (Hartshorn & Rovee-Collier 1997)); for 9-month-olds after 6 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 12-month-olds after 8 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 15-month-olds after 10 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998)); for 18-month-olds after 13 weeks ((Wojcik 2013) referring to (Hartshorn et al. 1998))
exposure of stimuli needed for learning for infants	2-month-olds need 3–6 minutes ((Wojcik 2013) referring to (Greco et al. 1986)); 3-month-olds need 2–3 minutes ((Wojcik 2013) referring to (Greco et al. 1990)); 6-month-olds need 1 minute ((Wojcik 2013) referring to (Hill et al. 1988))
words children in ages of 2–30 months hear from adults	12815 words per day from all adults (Gilkerson & Richards 2009); 3184 words per day from male adult (Gilkerson & Richards 2009); 9631 words per day from female adult (Gilkerson & Richards 2009); 520 conversational turns per day for 24-month-old child in a typical family (Gilkerson & Richards 2009)
range of values of daily child vocalizations for children so that lower end of range represent having parents that belong to lowest 20th percentile and higher end of range represents having parents that belong to the highest 20th percentile in respect to adult word count	for 2-month-olds about 550 daily child vocalizations (about same value for children of both talkative and untalkative parents) (Gilkerson & Richards 2009); 6-month-olds about 800–1000 daily child vocalizations (Gilkerson & Richards 2009); 12-month-olds about 1000–1500 daily child vocalizations (Gilkerson & Richards 2009); 18-month-olds about 1200–1800 daily child vocalizations (Gilkerson & Richards 2009); 24-month-olds about 1300–2200 daily child vocalizations (Gilkerson & Richards 2009); 36-month-olds about 1600–2700 daily child vocalizations (Gilkerson & Richards 2009); and 48-month-olds about 1700–2700 daily child vocalizations (Gilkerson & Richards 2009)
spoken words for persons in age range of 17–29 years	15669 words per day (men) (Mehl et al. 2007); 16215 words per day (women) (Mehl et al. 2007)
time used in school per week for students of ages of 6–17 years living in a family having computer with internet	33 h 54 min (6–8-year-olds) (Juster et al. 2004); 32 h 44 min (9–11-year-olds) (Juster et al. 2004); 33 h 15 min (12–14-year-olds) (Juster et al. 2004); 30 h 21 min (15–17-year-olds) (Juster et al. 2004)
time used in studying (excluding time used in school) per week for students of ages of 6–17 years living in a family having computer with internet	2 h 26 min (6–8-year-olds) (Juster et al. 2004); 3 h 31 min (9–11-year-olds) (Juster et al. 2004); 5 h 3 min (12–14-year-olds) (Juster et al. 2004); 5 h 20 min (15–17-year-olds) (Juster et al. 2004)
time used in reading per week for students of ages of 6–17 years living in a family having computer with internet	1 h 28 min (6–8-year-olds) (Juster et al. 2004); 1 h 42 min (9–11-year-olds) (Juster et al. 2004); 1 h 42 min (12–14-year-olds) (Juster et al. 2004); 0 h 58 min (15–17-year-olds) (Juster et al. 2004)
time used in being read to per week for students of ages of 6–17 years living in a family having computer with internet	0 h 12 min (6–8-year-olds) (Juster et al. 2004); 0 h 6 min (9–11-year-olds) (Juster et al. 2004); 0 h 3 min (12–14-year-olds) (Juster et al. 2004); 0 h 0 min (15–17-year-olds) (Juster et al. 2004)
time used in computer activities per week for students of ages of 6–17 years living in a family having computer with internet	1 h 8 min (6–8-year-olds) (Juster et al. 2004); 1 h 41 min (9–11-year-olds) (Juster et al. 2004); 4 h 5 min (12–14-year-olds) (Juster et al. 2004); 6 h 6 min (15–17-year-olds) (Juster et al. 2004)
time required to adopt professional proficiency in a foreign language by a native English speaker	ranging from 23–24 weeks or 575–600 class hours (language closely related to English, for example French) to 88 weeks or 2200 class hours (language which is exceptionally difficult, for example Arabic) (Sanatullova-Allison 2009)

11.7. Reading with comprehension

It has been shown that with a 140-item form of *vocabulary size test*, each item containing a multiple-choice question with four alternative definitions to choose from for a given concept, is capable of providing reliable and valid measure of vocabulary size of student ((Nation & Beglar 2007); (Beglar 2010)). We suggest that similarly a sufficiently long and diverse exploration path traversed in a hyperlink network representing conceptual relationships of a vocabulary could possibly relatively reliably measure the vocabulary size of student and also other characteristics defining the learner's abilities and success of learning. We think that while exploring in hyperlink network when a learner is required to select which of alternative hyperlinks to traverse next these selections cumulatively correspond to answering a series of multiple-choice questions. Based on a review of research about independent reading, Paul (2004) concludes that before transition at around third or fourth grade from "learning to read" to "reading to learn" a goal of 85 percent correct in a *comprehension quiz* is a reasonable goal for students but at later grades the greatest gains in reading achievement happened with about 93–96 percent correct in quizzes. Paul recommends that students should read books that introduce new vocabulary but not excessively which can bring frustration.

When learning relies on exploration in hyperlink network we think that finding the most educationally rewarding path can be supported also with solutions identified for *optimal stopping procedure* (i.e. marriage problem, secretary problem or best choice problem, also concerning Odds algorithm) and related to this it has been found that brain regions identified to take part in evidence integration and reward representation encode threshold crossings which trigger decisions about committing to choice (Costa & Averbeck 2013). Therefore while deciding among all n outgoing hyperlinks which outgoing hyperlink to traverse next from current concept and if learner must select or reject each of alternative outgoing hyperlinks one by one, we suggest that optimal strategy is to first directly reject about n/e of alternatives (here e denotes Napier's constant) and then select the next alternative that is better than all alternatives so far (or to select the last alternative) thus leading to that the probability of selecting the best alternative to converge towards $1/e$ (≈ 0.3679) when n increases, as motivated by results of Bruss (1984). Finding the shortest route that visits each node in a network once then finally returning to start node again, known as a *travelling sales man problem*, has shown to be a NP-hard problem but interestingly human performance to solve travelling sales man problem has been shown to be close to optimal (Acuña & Parada 2010), thus motivating exploiting human-like intuitive heuristics for efficient exploration in a network.

Soureshjani and Naseri (2011) mention based on previous meta-analysis (Swanburn & de Glopper 1999) that readers can achieve partial understanding of about 15 percent of unfamiliar words that they encounter in reading. Nagy et al. (1987) mention earlier results that students managed to *learn a word from context* with probability in the range of 15–22 percent when multiple-choice test was arranged within 15 minutes after reading a given text (Nagy et al. 1985). When Nagy et al. (1987)

carried out an another similar experiment the probability of learning a word from context was 5 percent when multiple-choice test was arranged 6 days after reading a given text showing additionally that students who had read a given text knew 3.3 percent more of its difficult words than students who had not read that text. Hunt and Beglar (2005) argue that the chance of retaining the meaning of a word is 5–20 percent.

Anderson et al. (1988) identified that the *amount of reading* of students of 5th grade was positively correlated with their reading achievement, and students achieving 98th percentile in reading test scores read 90.7 minutes per day and 4733000 words per year whereas students achieving 50th percentile read 12.9 minutes per day and 601000 words per year. Wu and Samuels (2004) showed experimentally that *time spent for independent reading* has a positive effect on reading achievement so that for low ability group a 15 minutes silent reading session appeared better for improving reading speed and comprehension whereas a 40 minutes session appeared better for improving word recognition, and for high ability group a 40 minutes session appeared better for all these skills.

McDaniel and Butler (2010) mention based on previous research that introducing so called *desirable difficulties* to the learner can have an important role in enhance learning (Bjork 1994). Inspiration for developing educational technology can be gained by taking a look at evolution of *readability research* that can be characterized by introduction of statistical analysis about text, generation of vocabulary frequency lists and definition of readability formulas based on semantic and syntactic measures to match reader with suitable text (DuBay 2004). Contributions coming from linguistics and cognitive psychology have increased complexity of models to consider motivation and background knowledge of reader that can affect readability.

Lewandowski et al. (2003) estimate that the *reading rate* for population in general is around an approximate value of 200 words per minute. For sufficient comprehension reading rate of at least about 200 words per minute (Anderson 1999) and average sentence length below 20 words (DuBay 2004) was suggested, thus resulting at least 10 sentences per minute. Based on *Flesch reading ease test* that considers those texts more difficult that have higher number of words per sentence and syllables per word, Lucassen et al. (2012) tried to estimate the readability of articles of the Wikipedia. When evaluating all available articles of the English Wikipedia the readability turned out to be poor due to 73.5 percent of the articles having measures below desirable Standard score (60) whereas with articles of Simple English Wikipedia 42.3 percent remained under Standard score although still 94.7 percent remaining under Easy score (80).

Some estimates about properties of supporting successful reading that have been just discussed are shown in Table 11.8.

Table 11.8. Some estimates about properties of reading with comprehension.

<i>An aspect of reading with comprehension to be considered</i>	<i>Values found in previous research concerning this aspect</i>
some requirements for reliable and valid vocabulary size test based on multiple-choice questions:	140 multiple-choice questions each having 4 alternative definitions (Nation & Beglar 2007)
an optimal strategy for optimal stopping procedure for selecting among n alternatives that must be selected or rejected one by one	first directly rejecting about n/e of alternatives (here e denotes Napier's constant) and then selecting the next alternative that is better than all alternatives so far (or selecting the last alternative) thus leading to that the probability of selecting the best alternative to converges towards 1/e (≈ 0.3679) when n increases (Bruss 1984)
coverage needed with comprehension quizzes for successful reading achievement	85 percent correct (until 3rd or 4th grade) (Paul 2004); 93–96 percent (from 3rd or 4th grade) (Paul 2004)
probability of learning a word from context	about 15 percent (partial understanding) ((Soureshjani & Naseri 2011) referring to (Swanburn & de Glopper 1999)); 15–22 percent (if multiple-choice test within 15 minutes) (Nagy et al. 1985); 5 percent (if multiple-choice test after 6 days) (Nagy et al. 1987)
chance of retaining the meaning of a word	5–20 percent (Hunt & Beglar 2005)
increase in level of knowing difficult words in a text after reading that text:	3.3 percent more (Nagy et al. 1987)
reading performance of student measured in time used and amount of text read	a student with average score in reading test: reads 12.9 minutes per day or 601000 words per year (Anderson et al. 1988); a student with excellent score in reading test: reads 90.7 minutes per day or 4733000 words per year (Anderson et al. 1988)
time spent for independent reading affecting reading achievement	<i>for low ability group:</i> a 15 minutes silent reading session was better for improving reading speed and comprehension whereas a 40 minutes session better for improving word recognition (Wu & Samuels 2004) <i>for high ability group:</i> a 40 minutes session was better than 15 minutes session for improving reading speed and comprehension and improving word recognition (Wu & Samuels 2004).
reading speed and comprehension:	<i>for population in general:</i> about 200 words per minute. (Lewandowski et al. 2003) <i>for sufficient comprehension:</i> at least about 200 words per minute (Anderson 1999) average sentence length below 20 words (DuBay 2004) thus resulting at least 10 sentences per minute
readability of text in the Wikipedia (Flesch reading ease test)	<i>English Wikipedia:</i> 73.5 percent below desirable Standard score (60) (Lucassen et al. 2012) <i>Simple English Wikipedia:</i> 42.3 percent under Standard score (60), still 94.7 percent under Easy score (80) (Lucassen et al. 2012)

11.8. Properties of compact networks

Small-world networks are networks that have a small average distance (or diameter) between nodes d so that for N nodes in network each having z neighbors the average distance can be estimated with formula $d = \log N / \log z$ (Newman 2000). *Scale-free networks* are networks whose nodes N have a probability of having k connections to other nodes that is proportional to $ck^{-\lambda}$ with parameters c and λ (Cohen & Havlin 2003). When parameter λ in range $2 < \lambda < 3$, average distance between nodes d in scale-free networks have been shown to be especially small following relation $d \sim \ln \ln N$ (Cohen & Havlin 2003).

Small-world networks have been considered as flexible and efficient structures that can be found inherently in many natural and sociological processes and it has been proposed that they have an important role for organizing and processing knowledge in biological neural networks ((Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010)). Bullmore and Sporns (2009) report that some studies with high spatial resolution have indicated that organization of functional brain networks holds scale-free properties ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008)) whereas some other studies indicated instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Small-world networks have been identified emerging in both social networks (Uzzi et al. 2007), wikis (Mehler 2006) and the world's largest wiki, the Wikipedia online encyclopedia (Ingawale et al. 2009). The Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)) and represents a hierarchical structure following so called power law, and the distribution of category sizes s has been estimated to be proportional to $s^{-\lambda}$ with λ having value of about 2.2 and a similar kind of power law decay emerged in link-based cluster size distribution (Capocci et al. 2008). When analysing the linking between articles, the hyperlink network of the Wikipedia has been found to be scale-free concerning ingoing links, outgoing links and broken links, and article sizes were lognormal distributed having linear growing median (Voß 2005). To explain evolution of scale-free network structures Barabási & Albert (1999) have suggested a model making new vertices attached preferentially to already well connected nodes.

It has been found that many features in the Wikipedia follow the *power law distribution*. These features include the number of distinct authors per Wikipedia article for articles having 5–40 authors ($\gamma \approx 2.7$), number of distinct articles edited per author ($\gamma \approx 1.5$), number of edits per author ($\gamma \approx 0.5$) and number of wanted articles per number of broken links pointing to them ($\gamma \approx 3$) (Voß 2005). Thus according to Voß the distribution of authoring of the Wikipedia seems to have accordance with *Lotka's law* which has been earlier identified in patterns of scientific publishing stating that the number of authors creating n contributions is approximately $1/n^a$ of number of those authors that make one contribution, with parameter a typically having value close 2 (Lotka 1926).

Small-world networks have been considered as an interesting form of networks due to their flexible and efficient way to represent structure and growth of connectivity of various natural processes ((Watts & Strogatz 1998); (Kleinberg 2000); (Newman 2003)). Also when trying to find consensus of agents and address synchronization problems in a network the small-world network has been considered to offer an especially efficient connectivity (Gu et al. 2010). Even when having very little knowledge of a given small-world network it has been shown that it is possible to route or navigate in it efficiently ((Kleinberg 2000); (Franceschetti & Meester 2006); (Sandberg 2008)).

Due to just mentioned scale-free small-world properties of *the Wikipedia* we think that the Wikipedia's hyperlink network can inherently provide relatively optimal structure for representation, management and exploration of *educational knowledge*.

Despite mixed acceptance from educators (Watson & Harper 2008), the *coverage* and *quality* of the Wikipedia is said to meet the level of respected encyclopedias (Giles 2005) and median survival time for vandalism edits is 11 minutes (Kittur et al. 2007). We think that a large part of curriculum has already been iteratively elaborated in the articles of Wikipedia. Wikipedia has many collaboratively agreed structural characteristics that intuitively support a learner to find personalized learning material at an appropriate level of complexity. We consider that the Wikipedia can adaptively support personalized learning of concepts and their relations. Each article defines a concept denoted by its title and its hyperlinks define relationships to other concepts.

According to experiment reported by Dolan (2011) based on full hyperlink network of Wikipedia version dating from 3 of March 2008, it takes *on average 4.573 traversals of hyperlinks* to get from any Wikipedia article to any other Wikipedia article. Dolan reports that at that time 3 March 2008 the Wikipedia contained 2301486 articles with 55550003 hyperlinks between them and furthermore there was a subentity of 2111480 articles which enabled traversing hyperlink chains between any articles belonging to this subentity. Dolan also reports that the article enabling the shortest connectivity to all other articles, so called departure center, was article named “2007” (average distance to other articles 3.45 hyperlinks) followed by article “Deaths in 2004” and article “2006”. Or, if excluding lists, years or days of year, the departure center was article “United Kingdom” (average distance to other articles 3.67 hyperlinks), followed by “Billie Jean King” (3.68 hyperlinks) and “United States” (3.69 hyperlinks).

In social networks of people, estimates have been made about the average length of the *shortest chains of relationships* connecting any two persons through intermediate persons. Famous result gained in 1960s by asking 296 arbitrarily selected individuals to send mail to a given target person through personal relationship chains showed that average distance was in the range *between 4.6 and 6.1 relationship steps* (Travers & Milgram 1969). Later resembling experiments have given support for an average distance in an approximately similar kind of range for other social networks. In May 2011, analysis of 721 million active users of Facebook social networking service (over 10 percent of the global population) and 68.7 billion links established between them showed that the average distance between any two users is about *4.74 relationship steps*, the value has had recently a decreasing trend but was apparently stabilizing (Backstrom et al. 2011). Furthermore, a related analysis showed that an active Facebook user has on average 190 direct relationships with other persons and a user having a median value of 100 friends has 27500 unique friend-of-friends (Ugander et al. 2011).

Forming a brief summary about evolution of network models that have been developed to manage network simulations, Prettejohn et al. (2011) mention *random network models of Erdős and Rényi* ((Erdős & Rényi 1959); (Erdős & Rényi 1960)) enabling shorter average paths than ordered networks but missing small-world and scale-free properties, *model of Watts and Strogatz* (Watts & Strogatz 1998) offering small-world properties but missing scale-free properties, *model of Barabási and Albert* (Barabási & Albert 1999) offering scale-free properties but missing small-world properties, and *model of Klemm and Eguílez* (Klemm & Eguílez 2002) offering both

small-world and scale-free properties. Bollobás and Chung (1988) determined that a graph consisting of an n -cycle and random matching has a diameter of about $\log_2 n$.

A network can be modeled by nodes located on a two-dimensional grid and expecting that each node has links to all nodes located within a certain amount of steps on grid. To enable *fast decentralized search* in a large network it is efficient to have such long-range link structure that a node v links to another node w with a *probability decaying along distance* so that probability is proportional to $d(v,w)^{-q}$ in which $d(v,w)$ denotes the distance of v and w as steps between them on a grid containing the nodes and q has value close to 2. Besides giving a more detailed proof for the just mentioned grid modeling approach, Easley and Kleinberg (2010) motivate this by an idea that in an area ranging from distance d to $2d$ the number of nodes on grid is proportional to d^2 and probability of linking to each node is proportional to d^{-2} and thus probability of random linking to some node is—due to d^2 and d^{-2} canceling out—approximately independent of value of d . Thus $q = 2$ seems to ensure a uniform distribution of long-range links over all different scales of hierarchical resolution.

In a network when using a routing algorithm based on only local information, the *number of nodes visited* before reaching the target node is minimized when probability of having a link between two nodes decays with the square of their distance and only with this condition it is possible to reach the target in logarithmic number of steps (Franceschetti & Meester 2006). In networks having *non-uniformly spaced nodes*, linking probabilities can be usefully determined so that a node v links to another node w based on $rank(w)$ that depicts w 's ranking position among all possible nodes linkable from v . With *uniformly spaced nodes*, when node w is at distance d from node v , node w is on circumference of a disc that contains, in approximation, d^2 nodes more closely positioned to v than w is, and thus $rank(w)$ can be approximated with d^2 . Therefore linking among uniformly spaced nodes from node v to node w with probability proportional to d^{-2} can be considered to suggest a generalization even for non-uniformly spaced nodes so that it resembles linking with probability $rank(w)^{-1}$ thus meaning *probability decaying along ranking position* (Easley & Kleinberg 2010).

Liben-Nowell et al. (2005) showed that efficient decentralized search is enabled in social networks when relying on *rank based friendship* in which the probability of person x having a person y as a friend is inversely proportional to the number of other persons being more closely positioned to x than y is. Adamic and Adar (2005) found out in analysis of *communicational social network* of an organization that the probability of linking between individuals as a function of the size g of the smallest organizational group into which both individuals belong to was proportional to $g^{-3/4}$.

Simsek and Jensen (2005) proposed with an empirical success an algorithm for making decentralized search in networks with a method that combines decision based on degree structure of neighboring nodes and based on how similar the neighboring nodes are to the target node in respect to attribute values. In this algorithm from node u the next step is taken to neighboring node v that maximizes *probability of direct link* to target node t . This relies on probability p_v that a particular one of friendships of node v will connect to target node t and thus formula $1 - (1 - p_v)^{\text{delta}_v}$ gives the probability that one of the delta_v friendships of v connect v to t .

Rodero-Merino et al. (2010) studied experimentally *random walks in one-hop replication networks* that have a property that every node knows the identity or resources of its neighbors and thus can reply to queries on their behalf. We interpreted some properties of random walks based on figures 7, 9 and 12 shown in their article (Rodero-Merino et al. 2010). In a random walk in a network the *probability of revisiting a node* increases as the number of hops increase and this effect is stronger in small-world network than in a random network. The probability of revisiting a node in a small-world network decreases when the average degree of network increases or when the number of nodes in network increases. In a small-world network containing 50000 nodes a random walk traversing 2000 hops managed to visit about 1600 nodes (about 3 percent) of the network when having an average degree of 10, and approximately the same result was gained when having an average degree of 30. Similarly, in a small-world network containing 50000 nodes a random walk traversing 10000 hops managed to visit about 7500 nodes (about 15 percent) of the network when having an average degree of 10 and about 8100 nodes (about 16 percent) when having an average degree of 30.

Rodero-Merino et al. (2010) showed experimentally that *coverage of a random walk* in small-world network grows faster when the average degree of network is higher and also that an *average search length* grows linearly with the network size and the bigger the average degree the shortest the searches are. In this context covered nodes include both visited nodes and their neighbors that are not required to be visited separately. In a small-world network containing 100000 nodes a random walk traversing 2000 hops managed to cover about 3500 nodes (about 3.5 percent) of the network having an average degree of 10 and to cover about 67000 nodes (about 67 percent) of the network having an average degree of 30. In a small-world network containing 10000 nodes an average search length was about 950 hops when having an average degree of 10 and an average search length was about 200 hops when having an average degree of 30. In a small-world network containing 100000 nodes an average search length was about 9500 hops when having an average degree of 10 and was about 2000 hops when having an average degree of 30. Random walks designed to avoid previous node and thus to decrease revisiting effect offered only a small increase in number of covered nodes in small-world network.

Some estimates about properties of networks affecting representing conceptual relationships that have been just discussed are shown in Table 11.9.

Table 11.9 part 1 of 2 (starts here and continues on next page). Properties of compact networks.

<i>An aspect of compact networks to be considered</i>	<i>Values found in previous research concerning this aspect</i>
<p>some characteristics shaping evolution of the Wikipedia and related networks</p>	<p><i>small-world networks</i> for N nodes in network each having z neighbors the average distance can be estimated with $d = \log N / \log z$ (Newman 2000); the Wikipedia is shown to be small-world network ((Ingawale et al. 2009); (Zesch & Gurevych 2007); (Masucci et al. 2011))</p> <p><i>scale-free networks</i> node's probability of having k connections $ck^{-\lambda}$ (Cohen & Havlin 2003); the average distance between nodes (if $2 < \lambda < 3$) proportional to $\ln \ln N$ (Cohen & Havlin 2003) the Wikipedia is shown to be scale-free network ((Zesch & Gurevych 2007); (Masucci et al. 2011); (Voß 2005))</p> <p><i>in the Wikipedia</i> distribution of category sizes proportional to $s^{-2.2}$ (Capocci et al. 2008); similar kind of decay for link-based cluster size distribution (Capocci et al. 2008); scale-free concerning: ingoing links, outgoing links, broken links (Voß 2005); article sizes lognormal distributed with linear growing median (Voß 2005); power law is found concerning: number of distinct authors per article when 5–40 authors ($\gamma \approx 2.7$) (Voß 2005), number of distinct articles edited per author ($\gamma \approx 1.5$) (Voß 2005), number of edits per author ($\gamma \approx 0.5$) (Voß 2005) and number of wanted articles per number of broken links pointing to them ($\gamma \approx 3$) (Voß 2005) the number of authors creating n contributions is approximately $1/n^a$ of number of those authors that make one contribution, with parameter a having value about 2 (Lotka's law) (Voß 2005) median survival time for vandalism in the Wikipedia is 11 minutes (Kittur et al. 2007)</p>
<p>some estimates for shortest connectivity in socially constructed networks</p>	<p><i>in the Wikipedia</i> (as of 3 March 2008) 2301486 articles with 55550003 hyperlinks between them (Dolan 2011); (sub-entity of 2111480 articles enabled traversing hyperlink chains between any articles belonging to this entity) (Dolan 2011); on average 4.573 traversals of hyperlinks to get from any article to any other article (Dolan 2011); departure center enabling the shortest connectivity to all other articles was article "2007" (average distance to other articles 3.45 hyperlinks) (Dolan 2011); an alternative departure center, if excluding lists, years or days of year, enabling the shortest connectivity to all other articles was article "United Kingdom" (average distance to other articles 3.67 hyperlinks) (Dolan 2011)</p> <p><i>in mailing experiment in USA</i> with 296 persons the number of steps connecting two persons in range 4.6–6.1 (Travers & Milgram 1969); <i>in Facebook social network</i> with 721 million users and 68.7 billion links between them the number of steps between two users 4.74 (Backstrom et al. 2011)</p> <p>a Facebook user has on average 190 direct relationships and a Facebook user having median value of 100 friends has 27500 unique friends-of-friends (Ugander et al. 2011)</p>

Table 11.9 part 2 of 2 (started on previous page and continues here). Properties of compact networks.

<i>An aspect of compact networks to be considered</i>	<i>Values found in previous research concerning this aspect</i>
<p>some estimates for modeling linkage in small-world networks</p>	<p>a graph consisting of an n-cycle and random matching has diameter about $\log_2 n$ (Bollobás & Chung 1988)</p> <p>to enable fast decentralized search in a large network a link from node v to node w is suggested with a probability proportional close to d^{-2} in which d denotes steps between them (Easley & Kleinberg 2010)</p> <p>in routing based on only local information, the number of nodes visited before reaching the target node is minimized when probability for a link between two nodes decays with the square of their distance and only then the target can be reached in logarithmic number of steps (Franceschetti & Meester 2006)</p> <p>linking among uniformly spaced nodes from node v to node w with probability proportional to d^{-2} can be considered to suggest a generalization even for non-uniformly spaced nodes that it resembles linking with probability $\text{rank}(w)^{-1}$ where $\text{rank}(w)$ depicts w's ranking position among all possible nodes linkable from v (Easley & Kleinberg 2010)</p> <p>to enable efficient decentralized search in social networks (relying on rank based friendship) the probability of person x having a person y as a friend is inversely proportional to the number of other persons being more closely positioned to x than y is (Liben-Nowell et al. 2005)</p> <p>the probability of linking between individuals as a function of the size g of the smallest organizational group into which both individuals belong to is proportional to $g^{-3/4}$ (Adamic & Adar 2005)</p> <p>decentralized search in networks has been suggested to be done so that from node u the next step is taken to neighboring node v that maximizes probability of direct link to target node t with formula $1 - (1 - p_v)^{\text{delta}_{u,v}}$ giving the probability that one of the $\text{delta}_{u,v}$ friendships of v connect v to t (Simsek & Jensen 2005)</p>
<p>some estimates for modeling exploration in small-world networks (concerning random walks in one-hop replication networks that have a property that every node knows the identity or resources of its neighbors and thus can reply to queries on their behalf)</p>	<p>in a random walk in a small-world network the probability of revisiting a node increases as the number of hops increase and decreases when the average degree of network increases or the number of nodes in network increases (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 50000 nodes a random walk: when traversing 2000 hops managed to visit about 1600 nodes (about 3.2 percent) with average degree of 10, and about the same result was gained with average degree of 30 (Rodero-Merino et al. 2010); when traversing 10000 hops managed to visit about 7500 nodes (about 15 percent) with average degree of 10 and managed to visit about 8100 nodes (about 16 percent) with average degree of 30 (Rodero-Merino et al. 2010)</p> <p>coverage of a random walk in small-world network grows faster when the average degree of network is higher, an average search length grows linearly with the network size, and the bigger the average degree the shortest the searches are (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 100000 nodes a random walk traversing 2000 hops managed to cover about 3500 nodes (about 3.5 percent) of the network having an average degree of 10 and to cover about 67000 nodes (about 67 percent) of the network having an average degree of 30. (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 10000 nodes an average search length was about 950 hops when having an average degree of 10 and an average search length was about 200 hops when having an average degree of 30 (Rodero-Merino et al. 2010)</p> <p>in a small-world network containing 100000 nodes an average search length was about 9500 hops for average degree of 10 and an average search length was about 2000 hops for average degree of 30 (Rodero-Merino et al. 2010)</p>

Chapter 12. Adoption of knowledge based on Wikipedia linkage and spaced learning along language ability levels

We think that the proposed methods and experiments that we have introduced in Chapters 4–9 seemed to encourage for further research that extends to so many directions that our current research efforts can manage to cover only a fraction of them due to both time and space constraints as well as computational complexities. Chapters 1–3 introduced some background to motivate development of our proposed methods and then Chapters 4–9 described development of our proposed methods. In Chapter 10 we have extended empirical motivation for suggested pedagogic gains of using proposed methods and then in Chapter 11 represented an overlook about principles that have been suggested in previous research to govern learning process as well as formation and exploration patterns of networks. Now we feel an emerging need to still present results of some additional experiments we have carried out to estimate even at coarse level the range of needed knowledge structures and computational resources required to sufficiently represent essential knowledge management processes in educational purposes based on conceptual networks relying on the hyperlink network of the Wikipedia when dealing with any typical learning topic encountered by a learner during her cumulative adoption of knowledge from early years of childhood to full maturity of adulthood. In this chapter we now represent results that have been published in publications [P7] and [P8] and we hope that these remarks can enable to give a final overlook to our research done for this dissertation and especially how we consider that the most interesting features in our proposed methods described in publications [P1]-[P6] and findings achieved with them could be fruitfully synthesized cumulatively to serve as a pedagogical framework for computer-assisted education in real educational context.

12.1. Cumulative exploration in conceptual network relying on spaced learning

Motivated by previous research, in publication [P7] we propose a new educational framework based on method that adjusts sequential ordering and spaced repetition of conceptual structures to support adoption of new knowledge. We decided to develop a framework that adapts methodology introduced in publication [P6] although using now a bit different terminology (as will be explained a bit later in this Subchapter 12.1).

For each learning topic it is possible to define a *learning topic vocabulary*, a set of concepts covering its essential pedagogical knowledge in respect to learner's needs, that

can be selected manually by learner or teacher, or be a high-frequency wordlist extracted for example from course book or lecture slideshow. To avoid semantic challenges we currently accept only nouns to vocabulary. Learning takes place in series of sessions, for example one session per day or per week, each one focusing on learning a *session vocabulary* that is a subset of the learning topic vocabulary. A *pedagogic conceptual network* is generated by linking concepts of session vocabulary based on the shortest paths in hyperlink network connecting corresponding articles of English edition of Wikipedia encyclopedia (<http://en.wikipedia.org>). Each Wikipedia article represents a concept depicted by its title entry and all departing hyperlinks in this article define its relationships to other concepts. To find satisfactory definitions and redirects in cases of disambiguation and synonyms we used Wiktionary dictionary (<http://en.wiktionary.org>). A compact *relation statement*—containing main verb with some adjacent words—is extracted from sentence surrounding the departing hyperlink in article text to depict semantic relationship of linked concepts. In each learning session, learner cumulatively strengthens adoption of concepts belonging to pedagogic conceptual network as method shows step by step a sequence of chained relation statements based on routing generated to traverse conceptual linking of network. After reading currently shown relation statement, learner presses button “Next” to proceed to seeing following one.

Please note that now in publication [P7] we use “session vocabularies” and “learning topic vocabularies” that have similarity with “key vocabularies” introduced in publication [P6] and similarly now in publication [P7] we use “pedagogic conceptual networks” that have similarity with “learning concept networks” introduced in publication [P6]. However, there are essential differences that we explain in the following.

In publication [P6] key vocabularies are identified by selecting a set of concepts with the highest frequencies in a representative text sample and each learning concept network is built by connecting concepts of the key vocabulary based on the shortest hyperlink chains between corresponding Wikipedia articles (as explained in Subchapter 9.2). Thus all arriving and/or departing hyperlinks of concepts of key vocabularies cannot necessarily become well exploited since the approach of selecting the highest-ranking concepts from text samples can exclude certain concepts that have important position in connectivity of hyperlink network. In contrast, in publication [P7] irrespective of what concepts belong to session vocabulary or learning topic vocabulary all arriving and/or departing hyperlinks for their concepts can typically become well exploited since pedagogic conceptual networks are generated with an approach that gradually expands *coverage of concepts* that have important position in connectivity of hyperlink network. Thus while in publication [P6] the proposed model highlighted combined use of three complementing perspectives, now in publication [P7] an emphasis is given to *gradually expanding conceptual networks*.²²

²² Following additional notions can be also made about relatedness between “session vocabularies”, “learning topic vocabularies” and “key vocabularies” as well as between “pedagogic conceptual networks” and “learning concept networks”. While there are different key vocabularies for each of three complementing perspectives (learner’s knowledge, learning context and learning objective) as explained

While traversing step by step each hyperlink in pedagogic conceptual network the learner becomes fruitfully exposed to associative mixture of old and new knowledge in a sequential process having tailored variation and repetition computed based on theory of *spaced learning*. We call this traversed route as a *learning path*. In the proposed framework our motivation to make the learner’s exploration in hyperlink network to be guided along principles of spaced learning originates from previous research that has shown benefits of spaced learning when compared to non-spaced learning, as already discussed in Subchapter 11.5. For example, a meta-analysis of 317 experiments (Cepeda et al. 2006) concluded that when compared to non-spaced learning, spaced learning of items consistently showed benefits regardless of retention interval, and learning benefits increased as time lags increased between learning presentations, and furthermore interstudy intervals producing maximal retention increased as retention interval increased. Principles of spaced learning has been motivated by findings in neurobiological activities (((Kandel 2001); (Fields 2005))) as explained in Subsection 10.6) and educational activities (((McKeown et al. 1985); (Hunt & Beglar 2005); (Karpicke & Roediger III 2007); (Cepeda et al. 2006); (Vlach & Sandhofer 2012))) as explained in Subsection 10.6), and computational methods to support learning have been proposed relying on spaced learning (((Wozniak & Gorzelanczyk 1994); (Pavlik & Anderson 2008))) as explained in Subsection 10.3 and Subsection 10.7).

Figure 12.1 (originally published as Figure 1 in publication [P7]) shows an excerpt of a learning path based on traversing concepts in a small pedagogic conceptual network going through a link chain Family → Child → Parent → Birth. Dotted arrows indicate possible traversal routes in network and solid arrows route that forms learning path this time. Concepts traversed recently and requiring spacing before being traversing again are in parenthesis. The learning path is shown to the learner as a sequence of following relation statements extracted from Wikipedia articles: “*Family* helps in socialization process of child”, “*Child* defines a relationship to parent or authority” and “*Mother* is a *parent* who performs the birth”.

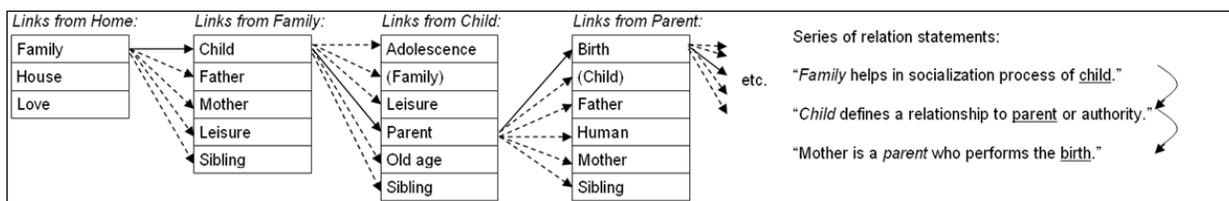


Figure 12.1 (originally published as Figure 1 in publication [P7]). An excerpt of a learning path and sequence of extracted relation statements shown to the learner.

in publication [P6], now in publication [P7] session vocabulary and learning topic vocabulary typically refer to such vocabulary entity that covers at least partially each of these three key vocabularies and thus also their shared vocabularies, i.e. concepts that are shared by each pair of learning concept networks, called as learner–context vocabulary, context–objective vocabulary and learner–objective vocabulary (as explained in Subchapter 9.2). Similarly now pedagogic conceptual network typically refer to such conceptual network that covers at least partially each of three learning concept networks (corresponding to learner’s knowledge, learning context and learning objective) and thus also their shared segments belonging to a minimal collection of the shortest hyperlink chains that connect all concepts belonging to a pair of learning concept networks, called as learner–context routing, context–objective routing and learner–objective routing (as explained in Subchapter 9.2).

User interface of a prototype tool implementing the framework has three parts. One by one, *learning path illustration area* shows to learner the relation statement encountered next along learning path, supplied with static or animated visualization. *Concept map area* enables learner to draw concept maps during initialization and intermittent retention tasks. *Control panel* enables learner to adjust manually all parameters affecting learning session if needed. Learning session is constrained by parameters and values adjusted by learner's activity. Based on learner's needs and teacher's advice or earlier testing, learner manually sets parameters of current session: *session vocabulary size*, *degree of new content*, *session duration*, *learning speed*, *degree of required adoption*, *degree of exposure repetition*, *degree of retention repetition*, *interval of exposures* and *interval of retentions* (defined in Table 12.1 (originally published as Table 1 in publication [P7])).

Table 12.1 (originally published as Table 1 in publication [P7]). Parameters of the framework affecting the learning during learning session.

<i>Parameter</i>	<i>Definition</i>
Session vocabulary size	Amount of different concepts traversable in pedagogic conceptual network during learning session
Degree of new content	Percentage of previously unknown concepts in session vocabulary to be exposed to during learning session
Session duration	Available time for learning session
Learning speed	Aimed rate to traverse links (relation statements) per minute along learning path
Degree of forgetting	Probability that the meaning of an encountered concept is not remembered in a random next future encounter
Degree of required adoption	Minimum value of probability that meaning of an encountered concept is remembered in a random next future encounter and which is a probability value considered sufficient for a concept to be declared as learned well
Degree of exposure repetition	Minimum number of spaced exposures of a concept needed to learn it well
Degree of retention repetition	Minimum number of spaced retentions of a concept needed to learn it well
Interval of exposures	Minimum time between spaced exposures of a concept needed to learn it well
Interval of retentions	Minimum time between spaced retentions of a concept needed to learn it well

As already motivated in Subchapter 5.2, for cumulative exploration in conceptual network relying on spaced learning to generate a learning path based on traversing concepts in a pedagogic conceptual network we want to offer support for learners representing cognitive style of field independence (as discussed in original analysis of publication [P7]) as well as learners representing cognitive style of field dependence (based on supplementing analysis made after publication [P7]). The experimental setup for recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network discussed in Subchapter 10.2 can be considered to have resemblance with the original analysis of publication [P7] whereas experimental setup for recall of shown hyperlinks forming the shortest paths in hyperlink network discussed in Subchapter 10.3 can be considered to have resemblance with the supplementing analysis made after publication [P7].

We now first explain the process to generate a learning path based on traversing concepts in a pedagogic conceptual network so that it should offer support for learners representing cognitive style of *field independence*, and a little bit later we explain briefly an alternative process so that it should offer support for learners representing cognitive style of field dependence.

When starting new learning session the method first evaluates the learner’s initial conceptualization level with following process. The method asks learner to indicate desired new learning topic by naming one or more familiar concepts about it which defines initial form of session vocabulary. These concepts are cross-linked based on the shortest hyperlink chains in Wikipedia to create initial form of the pedagogic conceptual network. Method now automatically extends initial form of pedagogic conceptual network to cover as many concepts as defined by parameter “session vocabulary size” by progressively uniformly linking new concepts to it according to how Wikipedia articles corresponding to current concepts have the nearest hyperlinked articles. These new concepts are also added to session vocabulary. Next, method generates a random excerpt of learning path containing 20 steps and shows its relation statements to learner in a sequence and then method asks learner to draw a concept map representing her best recall and understanding about concepts she just saw and how they were linked. Method compares how much concepts and their links in concept map overlap with hyperlink structure of pedagogic conceptual network, and degree of matching between them defines parameter *degree of forgetting*, on scale 0.05–1.00 (overlap of 5–100 percent). Then method supplies each concept of pedagogic conceptual network with a value *measure of adoption* defined as $(1 - \text{degree of forgetting})$, estimating learner’s probability to remember meaning of this concept in a random next future encounter.

Framework records evolution of learning path and learner can continue learning of previous session by loading from database learning paths and values achieved so far for each concept of learning topic vocabulary and pedagogic conceptual network. For each concept, framework keeps a record and updates five values. Besides “measure of adoption”, they include *measure of exposure repetitions* (number of spaced exposures of the concept so far), *measure of retention repetitions* (number of spaced retentions of the concept so far), *time between exposures* (average time between spaced exposures of the concept so far) and *time between retentions* (average time between spaced retentions of the concept so far). At each step of proceeding to next concept along learning path, all five values of that concept are updated. “Measure of adoption” is updated by formula based on cumulative multiplication of probabilities of forgetting (here index $n+1$ denotes new state and index n previous state):

$$\text{measure of adoption}_{n+1} = (1 - (1 - \text{measure of adoption}_n) \times (\text{degree of forgetting}))$$

When generating learning path, framework guides learner to traverse in pedagogic conceptual network at each step from current concept next to a concept having now the lowest “*measure of adoption*”, along the *shortest connecting hyperlink chain*. However, an additional restriction is that method aims to ensure fertile spacing between instances

of traversing same concept again according to value “*interval of exposures*”. If several concepts share the lowest value, framework guides learner to traverse to that concept which is encountered first with *breadth-first search* starting from current concept. Learning path is generated at each step to proceed next only to concepts directly linked from previous concept. Due to naturally emerging clustering hierarchy of hyperlink network connecting session vocabulary, framework can somewhat prioritize such routes that give additional probability for traversing hubs in pedagogic conceptual network to reach distant concepts and links. Learner should traverse concepts with defined learning speed within 10 percent margin or framework recommends learner to adjust her speed. If session vocabulary contains more unknown concepts than value “degree of new content” allows, framework first generates such learning path that traverses only inside a subset of session vocabulary having number of unknown concepts low enough to qualify “degree of new content”. When unknown concepts of subset later gradually become learned due to spaced repetition, traversable vocabulary (subset) is cumulatively extended with additional unknown concepts.

We think that learning process can benefit if suitable amount of personal initiatives and spontaneous interactivity on lower level of granularity is offered to learner during exploration in hyperlink network even if on higher level of granularity the framework itself makes decisions about which exploration routes are made currently available to the student based on theory of *spaced learning*. Thus for example the learner can be provided with a few alternative hyperlinks to proceed next and given an opportunity to actively select one of these according to his preference. Anyway we also think that to support adoption of concepts and also to cumulatively reinforce adoption of those concept that have not been yet fully adopted by student benefits from limiting the amount of available options during exploration thus contextually filtering out showing hyperlink alternatives leading to less relevant routes that might disturb concentration by excessive cognitive load.

Also it can be useful to let the student self intuitively and according to his own preference select routes to traverse as long as conditions based on spaced learning (that are automatically monitored on the background by the framework) become met and only after that gradually eliminate available hyperlinks shown to student and possibly indicating with a scale of color shades like traffic lights how much traversals remain currently still available for each hyperlink and how much the framework wants to promote proceeding each available hyperlink next. However it can be useful to show some alternative hyperlinks so that traversing them is not currently allowed (due to constraints based on spaced learning) but anyway the student has a possibility to see these alternatives to better adopt branching of exploration routes and how conceptual network enables diverse collection of parallel, crossing and overlapping routes and intermediate concept along paths when trying to find most optimal and descriptive routes connecting a pair of concepts.

With a spacing defined by parameter “interval of retentions”, method periodically interrupts proceeding along learning path with a *retention task* by asking learner to draw a concept map representing her best recall and understanding about concepts she just saw and how they were linked since the start of current learning session or since the

latest retention task. Method compares how much concepts and their links in concept map overlap with hyperlink structure of pedagogic conceptual network, and degree of matching between them redefines “measure of adoption” for all concepts involved and also “degree of forgetting”. All concepts belonging to session vocabulary need to become traversed in pedagogic conceptual network along learning path so many times and with sufficient spacing that finally—due to repeated cumulative exposure and retention—for each concept value “measure of adoption” reaches “degree of required adoption”, “measure of exposure repetitions” reaches “degree of exposure repetition” and “measure of retention repetitions” reaches “degree of retention repetition”. Now each concept of session vocabulary has reached enough exposures and retention to be declared as learned well. Then—or if session has lasted longer than “session duration”—session ends and method reports “measures of adoption” for each concept of session vocabulary and supplementing statistic about evolution of learning path, like number of traversals per each hyperlink. These results are stored so that adoption of vocabulary can flexibly continue in future learning sessions.

We have now just explained the process to generate a learning path based on traversing concepts in a pedagogic conceptual network so that it should offer support for learners representing cognitive style of field independence (as discussed in original analysis of publication [P7]), and next we explain briefly an alternative process so that it should offer support for learners representing cognitive style of *field dependence* (based on supplementing analysis made after publication [P7]). The alternative process relies on same fundamental logic as the original process explained in publication [P7] but while the original process provides to the learner few alternative hyperlinks to proceed next and gives an opportunity to actively select one of these according to his preference the alternative process now more strictly limits providing alternative hyperlinks (possibly providing only one at time) and while retention task for the original process asked learner to draw a concept map representing her best recall of conceptual relationships just seen the alternative process asks to fill in a multiple-choice questionnaire about conceptual relationships just seen so that only one alternative is correct.

Promisingly, learning paths suggested by framework seemed to match well learner’s needs when learning paths were generated by using such parameters that correspond to learning practices typical for successful spaced learning. In accordance with previous research, we suggested in publication [P7] based on our preliminary testing to use following approximate values for parameters.

“Session duration” of about 30 minutes and “session vocabulary size” of about 100 concepts may enable enough variation and spaced repetition (motivated by result that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes, and thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures (Fields 2005) and motivated by result that vocabulary of 100 concepts matches well with values of learning speed and degree of exposure and degree of retention that we

define and explain just below since with learning speed of 10 traversed concepts per minute each of 100 concepts of session vocabulary becomes on average encountered 3 times in 30 minutes of session duration).

To avoid cognitive overload it seems promising to have about 5 percent as “degree of new content” and about 85 percent as the “degree of forgetting” (motivated by result that 95 percent coverage is sufficient for reasonable comprehension of text ((Nation & Waring 1997) referring to (Laufer 1989)) and motivated by result that the chance of retaining the meaning of a word is 5–20 percent (Hunt & Beglar 2005)). To maintain continuity of comprehension, “learning speed” could be about 10 traversed concepts per minute (motivated by result that for sufficient comprehension reading rate of at least about 200 words per minute (Anderson 1999) and average sentence length below 20 words (DuBay 2004) has been suggested thus resulting at least 10 sentences per minute corresponding to traversing a hyperlink with a relation statement).

For each concept at least value 3–5 is suggested as “degree of exposure repetition” and “degree of retention repetition”, and 10 minutes as “intervals of exposures” and “interval of retentions” to ensure it becomes learned (motivated by result that to activate a gene for long-term memory formation in a synapse of mouse there is a need for at least three action potentials at least 10 minutes apart, and once the gene is activated it produces required proteins for about 30 minutes, and thus when learning a new knowledge item also human brain might benefit from 3–5 short distinct exposures separated by 10 minutes and then additional 30 minutes for continuous exposures (Fields 2005)). “Degree of required adoption” could be 95 percent so that with this probability the meaning of each concept is remembered in random next future encounter (motivated by result that 95 percent coverage is sufficient for reasonable comprehension of text ((Nation & Waring 1997) referring to (Laufer 1989))).

In publication [P7] we provided preliminary results of our experiment (n=73) concerning recall of selected hyperlinked concepts and shown hyperlinked concepts in hyperlink network after exploration task. We carried that experiment to enable to analyze the process of exploration tasks in hyperlink network of the Wikipedia and to give verification to suggested educational benefits gained with these exploration tasks. Based on further analysis after publishing publication [P7] we presented partially different, corrected results of that experiment in Subchapter 10.2. After publishing publication [P7] we have carried out an extended analysis discussed in Subchapter 10.2 and those supplementing later experiments seem to fruitfully verify findings of our earlier preliminary testing we just discussed here in Subchapter 12.1 including suggested approximate values for parameters of proposed framework. We think that features related to three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and features shown in Table 10.10, as discussed in Subchapter 10.2, can be considered to at least indirectly give strong experimental support to our suggestions here in Subchapter 12.1 that the student’s exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning.

In publication [P7] we propose that the student’s exploration along learning path is supplied with a set of visualizations based on main verb identified in relation statements

extracted from sentences surrounding hyperlinks in Wikipedia articles. In previous research it has been shown that kindergarten children can learn to use strategies based on semantic integration of meaningful sentences relying on pictographs and these strategies can be transferred to other similar tasks (Ryan et al. 1987). An early influential work was defining international picture language suggested for varied educational purposes based on agreed compact visualizations (Neurath 1936). Despite being popular, many proposed abstract visual symbolic languages can be challenging to intuitively understand especially in chained and agglomerated conceptual relationships, and critical empirical evaluation of their suggested benefit for comprehension has been largely missing (Lin & Biggs 2006). Watson and Moritz (2001) proposed a developmental model with four response levels dealing with how students arrange pictures to represent data in a pictograph, how they are interpreted and used to make predictions. It has been shown that despite somewhat decreased use of pictographs in later school years they can be used to support diverse tasks for example in counting skills and appreciation of variation and uncertainty in prediction (Watson & Kelly 2003). Gordon proposed using interactive comics for collaborative learning by letting online discussion to be represented with learner-driven editing of contents of a four-frame comic strip (Gordon 2006). It is typical that even complex abstract visual notations convey meanings that have diverse references to specific languages and cultural contexts (Unger 2003).

In the framework of publication [P7] we suggest that while the learner proceeds the links in pedagogic conceptual network, each shown relation statement is supplied with a visualization to help conceptualization of the relationship between the pair of concepts of the current link. While traversing the learning path, at each step the learner is provided with a list of concepts linked to from the current concept and relation statements depicting these relationships, supplied with a visualization to help conceptualization of the relationship between the pair of concepts of each link. Figure 12.2a shows an example of this list when the current concept is Parent and the concepts linked to from current concept include Birth, Child, Human, Father, Mother and Sibling. When the learner, based on her needs and intuition, selects with mouse one of the linked concepts (shown in the column “Next concept”), her exploration proceeds one step further in the pedagogic conceptual network so that the selected concept becomes now current concept and the list becomes updated to represent which concepts are linked to from this new current concept.

Visualizations, shown at each step of proceeding links in pedagogic conceptual network, are collaboratively created and edited by community of learners in wiki style with an aim to gradually enhance illustrative effect of visualizations and at the same to enable collaboratively individual learners to increase their personal skills of creating works of illustrative visual art and adoption of evolving conventions of visualization. Each visualization can be done with any technique but is supposed to be in a form we call as *drawn sketch of illustrative visual art*, i.e. a drawing created quickly intuitively to represent the learner's, who is drawing, current personal conceptualization about current relation statement in a form that is as compact, illustrative and universally understandable as possible. Visualizations for each relation statement should be

collaboratively created and edited so that their compact yet illustrative nature becomes constantly enhanced and an ontology becomes cumulatively defined for network of visualizations about the learning topic and for the learner's personal conceptualization concerning it. Aim is that while exploring visualizations each student can learn about their traditional yet evolving conventions and on the other hand further contribute to defining at least partially shared language of visualization based on drawn sketches, thus closely resembling ideology of developing information graphics that visualize data innovatively.

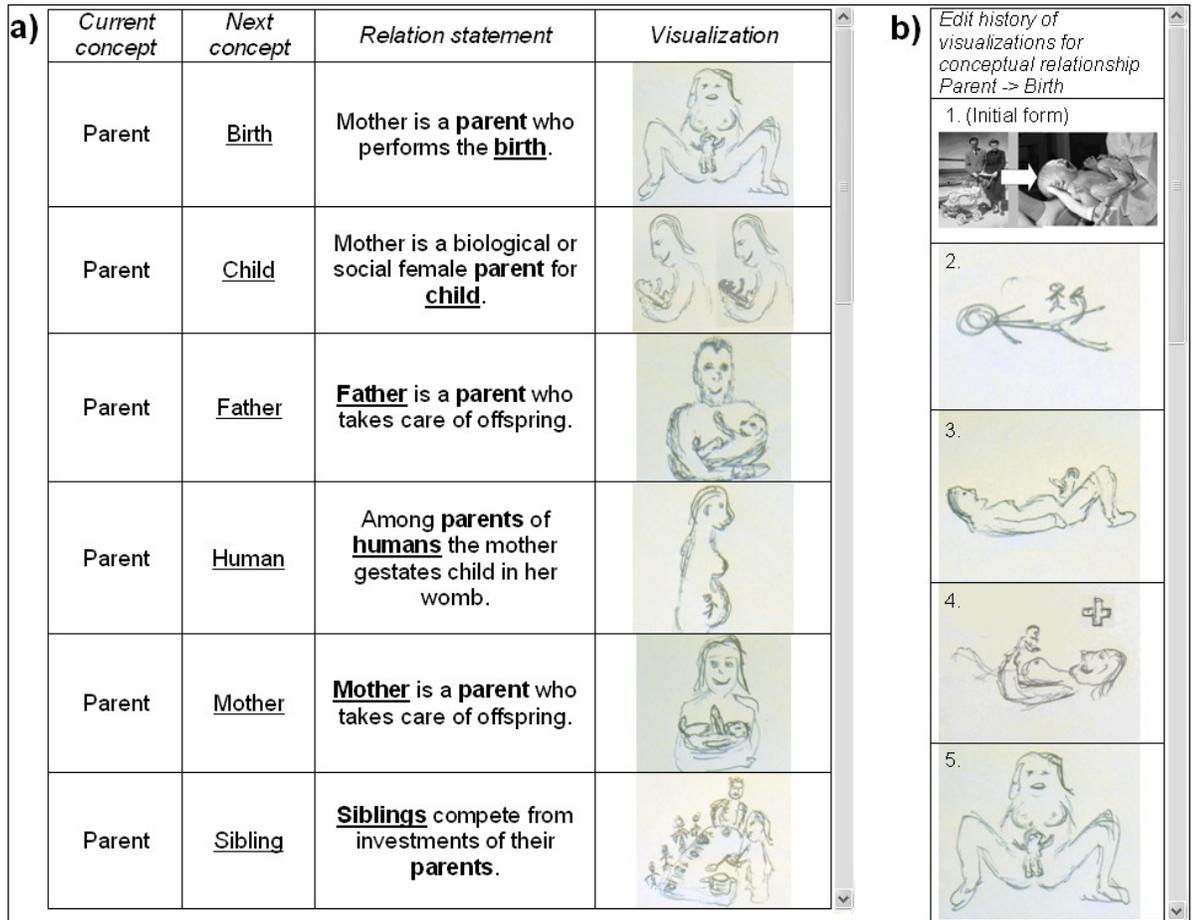


Figure 12.2. a) A list of concepts linked to from the current concept and relation statements depicting these relationships, each supplied with a visualization, that are shown to the learner while traversing step by step along the learning path. b) A view from edit history showing few consecutive temporal versions of visualizations created to illustrate conceptual relationship leading from Parent to Birth. (For the license of two photos, both stored at Wikimedia Commons, see http://commons.wikimedia.org/wiki/File:PikiWiki_Israel_4062_A_pair_of_immigrants_and_a_child.jpg and <http://commons.wikimedia.org/wiki/File:HumanNewborn.JPG>.)

By clicking with mouse at any visualization the learner gets full access to edit history of this visualization an enabling to create a new version of this visualization based on earlier versions and according to her own intuition. A full access to edit histories of all visualizations is provided with an educational aim that the modifications and refinements to visualizations could be done so that a gradual cumulative development of visualization is achieved based on the earlier versions. In case of largely unsatisfied version there remains a direct access to revert to earlier versions of visualization. In Figure 12.2b is a view from edit history showing few consecutive temporal versions of visualizations created to illustrate conceptual relationship leading from Parent to Birth.

Each visualization consists of two *concept pictographs* representing concepts, extracted from the images of corresponding Wikipedia articles or queried from Wikipedia Commons open image database (<http://commons.wikimedia.org>), and a *transitional effect* (either static or dynamic) representing the relationship between concepts based on extracted relation statement. Static transitional effects consist of semitransparent still images placed over and between concept pictographs following visualization conventions of story-telling in comic strips and dynamic transitional effects consist of coordinating animation implementing movements and transformations of concept pictographs following visualization conventions of story-telling in cinema. A database of visualization conventions is collaboratively maintained for most frequently encountered key terms in relation statements and is queried to find most matching transition effect. To avoid semantic challenges transition effect is currently selected based on main verb identified in relation statement after it is supplied with part-of-speech tagging.

To aid development of effective visualizations the framework provides inspiration for further editing by creating an initial form of visualization which consists of two *concept pictographs* representing concepts of currently traversed relationship, extracted from the images of corresponding Wikipedia articles or queried from Wikimedia Commons open image database (<http://commons.wikimedia.org>), and a static *transitional effect* representing the relationship between concepts based on extracted relation statement. Static transitional effects consist of semitransparent still images placed over and between concept pictographs following evolving visualization conventions of story-telling in comic strips. A database for these visualization conventions is collaboratively maintained for the most frequently encountered key terms in relation statements and is queried to find most matching transition effect. To avoid semantic challenges transition effect is currently selected based on main verb identified in relation statement after it is supplied with part-of-speech tagging. In Figure 12.2b an initial form of visualization is generated by connecting a photo of parents (retrieved from Wikimedia Commons with query about Parent) and a photo of a newborn (extracted from Wikipedia article about Birth as of 1 November 2012) with an arrow indicating causality.

While the learner participates in collaborative editing of a visualization, reviews its edit history and explores the initially suggested visualizations consisting of concept pictographs and transitional effect she becomes involved in diverse complementing processes of adoption of evolving conventions of visualization and skills of creating

works of illustrative visual art. All activities of browsing in a conceptual network and creating and editing visualizations are recorded to a log which offers a systematic way to track and analyze learning process thus helping educators and learners themselves in management, modeling and coordination of conceptualization of new knowledge, enhancing personal creative skills and identifying specific areas needing support.

12.2. Cumulative exploration in conceptual network relying on growing vocabularies based on language ability levels

Motivated by previous research, in publication [P8] we propose a new educational framework based on guided exploration in small-world networks relying on hyperlink network of the Wikipedia online encyclopedia in which hyperlinks between articles define conceptual relationships. Educational material is presented to student with cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the distribution of enabled hyperlinks connecting concepts belonging to current vocabulary according to requirements of learning objective, learning context and learner's knowledge. Besides developing a computational method to manage educational material with conceptual networks and to explore the shortest paths between concepts of vocabulary (especially highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts), we have also experimentally estimated properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to six language ability levels.

Previous research has shown that *small-world networks* offer efficient compact link structures that seem to exist in many natural processes such as social networks (Uzzi et al. 2007). Using small-world networks can help to minimize paths required to form connectivity between nodes of the network and to maintain this property also when the network grows or experiences other modifications. Small-world topology has been identified structurally and functionally in human brain networks ((Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010)) and thus we think that representation of knowledge in form of small-world networks should be encouraged to support various knowledge management tasks and especially learning. Currently one of the biggest freely accessible knowledge resources is collaboratively built Wikipedia online encyclopedia and that has been shown to naturally represent properties of a small-world network (Ingawale et al. 2009).

Besides holding general small-world properties it has been identified furthermore that the Wikipedia holds *scale-free small-world properties* ((Zesch & Gurevych 2007); (Masucci et al. 2011)) and motivated by this we suggest that representation of knowledge for various purposes can benefit from having not only general small-world properties but furthermore having scale-free small-world properties. As already discussed in Subchapter 11.8, concerning network models Prettejohn et al. (2011)

mention the model of Klemm and Eguílez (Klemm & Eguílez 2002) that offers both small-world and scale-free properties. Also as already discussed in Subchapter 11.8, Bullmore and Sporns (2009) mention that some studies with high spatial resolution have indicated that in organization of functional brain networks scale-free properties hold ((Eguíluz et al. 2005); (Van den Heuvel et al. 2008)) and some other studies indicate instead an exponentially truncated power law distribution ((Achard et al. 2006); (Bassett et al. 2006)).

Motivated by previous research we propose in publication [P8] a new framework to support learning based on knowledge structures inspired by the hyperlink network of the Wikipedia and we supply this proposal with some promising experimental results relying on our empirical analysis of properties of conceptual networks that we have generated based on the Wikipedia.

We propose a method for *cumulative adoption of vocabulary* supported by representations of vocabulary in knowledge structures that are based on a small-world network (and possibly a scale-free version of small-world network being the most preferable). We think that due to properties of small-world network emerging inherently in various instances of nature ((Uzzi et al. 2007); (Perc 2007); (Pajevic & Plenz 2009); (Stratton & Wiles 2010); (Wang et al. 2010); (Bullmore & Sporns 2009)), it is possible that learning of new knowledge can get useful support if new pieces of knowledge can be added to learner's previous knowledge entities in mind in a process that can be represented by *building a scale-free small-world network* and through its modification and exploration. We think that instead of just one small-world network there can be a great number of diverse parallel and partially overlapping and multidimensional small-world networks that can be used at the same time to represent knowledge both in educational material, such as texts, and in the learner's mind. We think that among students there are large individual differences in student's mental small-world networks representing his previous knowledge entity. Therefore to make new pieces of knowledge to become sufficiently fit into previous knowledge entity of student during learning process it is useful to offer personalized forms of representation of educational material.

Ellis (2008) explains emergence of dynamic cycle of language use so that high-frequency of grammatical language elements can cause their erosion and homonymy thus affecting perception, learning and eventually language usage. Ferrer i Cancho and Solé (2001) mention that sequential co-occurrences of words in sentences can be represented in network form that shows small-world properties enabling average number of steps needed to proceed along links from a word to any other word to be in range of 2–3 steps. Kinouchi et al. (2002) explain how a thesaurus holds small-world properties and when performing a walk in corresponding conceptual network always leads to a cycle whose period depends on desired memory window (i.e. how many preceding visited nodes remain to be avoided at each step). Networks having small world properties and exhibiting a degree distribution with a scale-free tail can be gained based on random texts generated with a word frequency that follows a power law (Brede & Newth 2008).

We think that our just discussed suggestion to support learning with knowledge structures having properties of small-world network (possibly preferably scale-free small-world network) can have some additional support from our previous analysis in Subchapter 10.2 concerning properties of three sets of eleven highest-ranking concepts in “hyperlink network of 55 concepts” based on Table 10.9 and properties of exploration in hyperlink network discussed based on Table 10.10, and previous analysis in Subchapter 12.1 about that the student’s exploration in hyperlink network can benefit from having tailored variation and repetition based on theory of spaced learning.

An influential early work aiming to describe age-related development of a *learner’s vocabulary* is a wordlist proposed by Dale and Chall (1948) defining 3000 words that were known by 80 percent of children attending school at grade 5. Based on British National Corpus XML edition ((Berglund 2007); (British National Corpus XML edition 2007)) containing tagging about contributing individuals of text and speech samples it has been possible to identify *variations of vocabularies* used by people of varying ages and to estimate how core vocabularies can form and evolve.

Hanhong and Fang (2011) identified that higher lexical coverage was gained when core vocabulary was selected based on word's dispersion index and distributed frequency in different age groups instead of raw frequency. Hanhong and Fang also found out that under 15-year-olds relied more on core vocabulary than older persons and along age increase core vocabulary of over 15-year-olds maintains a stable proportion of their vocabulary size. Furthermore Hanhong and Fang found out that each age group appears to acquire more core words relying on age-related frequency than raw frequency. Cromley (2005) empirically analysed *reading comprehension* in respect to five contributing variables of vocabulary, background knowledge, interference, strategy and word reading suggesting based on path analysis that vocabulary and background knowledge which are two of the most distal variables give the biggest contribution to comprehension. Previous research has identified how the amount of daily vocalization evolves along age (Gilkerson & Richards 2009) and gender based differences of talking (Mehl et al. 2007) as well as time use for students along age covering for example school, additional studying, reading, being read to and for computer activities (Juster et al. 2004), as discussed in Subsection 10.7. Previous research has also identified annual amount of reading depending on student’s reading test score (Anderson et al. 1988) and annual adoption of new concepts to student’s vocabulary ((Nation & Waring 1997); ((Lehr et al. 2004) referring to ((Anderson & Nagy 1992); (Anglin 1993); (Beck & McKeown 1991); (White et al. 1990)); ((Kuhn & Stahl 1998) referring to ((Graves 1986); (White et al. 1990))), as discussed in Subsection 10.8 and Subsection 10.2.

Trying to keep our analysis transparent and comparable for other research in this field we carried out further experiments with such vocabularies that are based on generally accepted recommendations about measuring a person’s evolving language ability along consecutive stages of learning and empirically identified representative conceptual distributions for each of these stages.

To address these aims, we considered that *Common European Framework of Reference for Languages* (CEFRL) is useful since it offers guidelines about how to

measure language ability with six progressive levels that have been supplied with illustrative descriptors created and scaled with Rasch modelling based on Swiss surveys in 1994–1995 covering 300 teachers and 2800 learners ((Council of Europe 2001); (North 1996/2000)). These six levels of language ability in increasing order of expertise have been labeled with names *A1 (Breakthrough)*, *A2 (Waystage)*, *B1 (Threshold)*, *B2 (Vantage)*, *C1 (Effective operational proficiency)* and *C2 (Mastery)*. First two levels have been classified to represent abilities of a basic user, two next ones abilities of an independent user and two last ones abilities of a proficient user.

While establishing CEFRL has enabled efforts to define vocabularies needed for each language ability levels that can be compared between various European languages large incompatibilities have been identified concerning the size of sufficient vocabularies for each language ability level and some *vocabulary sizes* have been suggested in the following ranges: 400–3300 words for level A1, 800–4000 words for level B1, 1100–6800 words for level B2 and 3300–30000 words for level C2 (Kusseling & Decoo 2010). Since defining cut-off points between language ability levels is a subjective process it has been suggested that each level can be further divided hierarchically to sublevels with a branching approach that enables to address local needs while still maintain easy positioning in respect to commonly shared higher-level framework.

Level C2 (Mastery) has been defined so that it does not imply abilities of a native-speaker but instead such precision, appropriateness and ease with the language that typically belong to *highly successful learners*. Along formation of six levels of language ability of CEFRL some simple general task were identified in the Swiss surveys that were scaled below level A1 but can be defined as objectives for *beginners* of language learning, including making simple purchases, asking and telling time-related information, using basic greetings and expressions of politeness, filling easy forms with personal details and writing a simple postcard.

Working document of European Commission (European Commission 2012) mentions estimates made by non-profit assessment organisation Cambridge ESOL (meaning Cambridge English for Speakers of Other Languages) now known as *Cambridge English Language Assessment* (Cambridge English for Speakers of Other Languages (ESOL) / Cambridge English Language Assessment 2013) about how many *guided hours of learning* are required to reach the language ability levels A2-C2 of CEFRL including 180–200 hours for A2, 350–400 hours for B1, 500–600 hours for B2, 700–800 hours for C1 and 1000–1200 for C2.

Based on several hundred thousand examination scripts of *Cambridge Learner Corpus* and multi-billion word *Cambridge English Corpus* and sponsored by Council of Europe there has been an effort to define English vocabulary covering each of six language ability levels of CEFRL and this has been resulted in formation of *English Vocabulary Profile* that is a database aiming to represent all words and phrases learners know at each of six levels of CEFRL (Capel 2013). From online database of English Vocabulary Profile (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A) offered by Cambridge University Press we retrieved in June-July 2013 all words and phrases belonging to each of six language ability level ranging from A1 to

C2. Thus we gained a series of *cumulative vocabularies* of six language ability levels of English Vocabulary Profile ranging from A1 to C2.

Since the six vocabularies gained from English Vocabulary Profile seemed to express such gradual evolution of a learner's vocabulary that are not clearly fixed to specific ages of the learner it seemed interesting to parallel English Vocabulary Profile to a resembling series of vocabularies that are fixed to specific age of the learner, especially in years of childhood and early youth. In this respect we considered that a useful resource is *Oxford Wordlist* that defines high-frequency wordlists for five consecutive strongly age-related categories of learners. Oxford Wordlist has been created based on writing samples collected in Australian schools in 2007 from about 1000 students of *three first school levels* (labeled somewhat confusingly as "Preparatory" (1891 samples), "Year 1" (951 samples) and "Year 2" (934 samples)) gaining over 160000 words (Lo Bianco et al. 2008) and in 2009 from 896 students of *fourth and fifth levels of school* (labeled again somewhat confusingly as "Year 3" (1437 samples) and "Year 4" (1251 samples)) gaining over 315000 words (Bayetto 2010). According to our understanding, the last four of these five school levels correspond approximately to ages ranging from 6- or 7-year-olds to 9- or 10-year-olds and Preparatory level corresponds to a bit younger ages.

From online database of Oxford Wordlist (<http://www.oxfordwordlist.com/pages/search.asp>) we retrieved in June-July 2013 all words belonging to high-frequency lists of each of five school levels ranging from Preparatory level to Year 4 level, when performing downloading the only setting we varied was school year, thus keeping settings concerning gender, language, indigenusness, school setting, location and text type always at option "any". In further analysis we consider that the series of high-frequency word lists of five school levels of Oxford Wordlist can sufficiently well represent a series of *partially cumulative vocabularies* of these five school levels and thus we refer to each of these high-frequency word lists with term vocabulary. Even if this our decision is somewhat coarse we considered it still sufficiently useful to enable to get some preliminary results when generating cumulative conceptual networks.

It appeared to us that the series of vocabularies in English Vocabulary Profile can reflect vocabulary needs belonging to English-for-secondary language having varying ages that largely represent already maturity and culturally diverse global backgrounds whereas series of vocabularies of Oxford Wordlist can reflect vocabulary needs belonging to specific age categories of childhood and early youth having culturally somewhat shared localized national context (i.e. Australia).

Table 12.2 shows the *amounts of words* we retrieved from online databases of both English Vocabulary Profile and Oxford Wordlist. To keep our new experimental setup sufficiently simple and to maintain comparability with our earlier experiments we decided to limit our further analysis concerning words retrieved from Oxford Wordlist and English Vocabulary Profile only to common nouns. The words of English Vocabulary Profile are inherently labeled with part-of-speech tags thus helping to extract only nouns. Since we did not have access to any part-of-speech classification concerning Oxford Wordlist (i.e. in available listings of Oxford Wordlist words were

not labeled with part-of-speech tags) in further analysis we decided to contrast each of five high-frequency wordlists of Oxford Wordlist with full list of nouns extracted from vocabulary of range of language ability levels A1–C2 of English Vocabulary Profile. Thus if a word belonging to a high-frequency wordlist of Oxford Wordlist was found to exist also in a full list of nouns extracted from vocabulary C2 of English Vocabulary Profile then this word was considered as a noun also in this high-frequency wordlist of Oxford Wordlist. Even if this contrasting process possibly caused some concepts to be incorrectly accepted to be nouns in high-frequency wordlists of Oxford Wordlist we considered that this process was still sufficiently useful to enable to get some preliminary results. Please note that in following analysis the given exact values that we have computed based on vocabularies we retrieved from Oxford Wordlist and English Vocabulary Profile can contain unintentional small inaccuracies due to challenging computational process. Appendix AA shows all unique nouns we retrieved in June–July 2013 from cumulative vocabularies of English Vocabulary Profile for six language ability levels ranging from A1 to C2. Appendix AB shows all unique nouns in high-frequency lists we retrieved in June–July 2013 from Oxford Wordlist (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile) for five school levels ranging from Preparatory to Year 4.

Table 12.2. Properties of cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and six language ability levels of English Vocabulary Profile ranging from A1 to C2.

<i>Oxford Wordlist</i>			<i>English Vocabulary Profile</i>		
School level	Unique words in high-frequency list	Unique nouns in high-frequency list (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile)	Range of language ability levels reached so far	Unique language items (words or phrases)	Unique nouns
Preparatory	1923	685	A1	785	305
Year 1	2364	811	A1–A2	2382	880
Year 2	3041	1008	A1–B1	5327	1761
Year 3	4808	1412	A1–B2	9502	2707
Year 4	4949	1445	A1–C1	11908	3198
			A1–C2	15715	3710

From Table 12.2 it can be seen that when a learner reaches the range of language ability levels A1–C2 of English Vocabulary Profile she is expected to know 15715 *unique language items*. Among these 15715 language items we identified 5853 *unique words or groups of words* supplied with a part-of-speech tag signifying adjective, adverb, conjunction, determiner, exclamation, noun, preposition or pronoun (some words or groups of words were supplied with more than one parallel part-of-speech tags). With a closer examination, among these 15715 language items belonging to range of language ability levels A1–C2 we identified 3710 *unique nouns*.

We generated *conceptual networks* relying on the hyperlink network of the *Wikipedia* (as of in June–July 2013) connecting collections of nouns having gradually increasing sizes as indicated in Table 12.2 for both Oxford Wordlist and English

Vocabulary Profile. Please note that in contrast with earlier analysis largely relying on Wikipedia hyperlink network dating from the beginning of March 2008 we used in this further analysis Wikipedia hyperlink network dating from late June and early July 2013.

Concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered *cumulative* so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only *partially cumulative* since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

However, it needs to be noted that, as show in Table 12.2, our analysis with collections of nouns having various sizes can be expected to represent indirectly *coverage of vocabulary* that is much larger than the number of nouns alone. Thus for example according to Oxford Wordlist a learner who has adopted already 1445 highest-ranking nouns of English (that can reflect vocabulary needs of school level “Year 4”) can be expected to have probably adopted at the same time already 4949 words altogether (i.e. these 4949 words containing words from also other word classes than just nouns) and according to English Vocabulary Profile a learner who has reached range of language ability levels A1–C2 can be expected to manage 3710 nouns but at the same time probably already 15715 language items altogether. We think that the range of vocabulary sizes we decided to use in our analysis can sufficiently well approximate vocabulary level processes of learning and knowledge management in human mind since our vocabulary sizes quite well approach and at least partially reach the range of vocabulary sizes suggested in previous research as suitable for reasonable human understanding.

With our method educational material is presented to student with cumulative conceptual networks based on hyperlink network of Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the *distribution of enabled hyperlinks* connecting concepts belonging to current vocabulary according to requirements of learning objective, learning context and learner’s knowledge. So far our method accepts only nouns to vocabularies since hyperlinks in the Wikipedia are typically defined to connect nouns but also other part-of-speech could be possibly exploited with a resembling approach.

Thus for *life-long learning* an ultimate aim can be to reach a maximal coverage of the conceptual small-world networks representing all human knowledge and besides that even some personal contribution could be done to supplement this heritage of human knowledge through own writings and other forms of conveying new knowledge to the community (and possibly a scale-free version of small-world network being the most preferable). On the other hand, we think that all knowledge entities can be seen to consist of a complex collection of interconnected, overlapping and nested small-

world networks so that each separate new learning topic can be considered to be learned as an own specific small-world network that becomes gradually more and more connected also to other small-world network structures held already so far in the mind of student.

When creating a hyperlink network of vocabulary based on hyperlink network of the Wikipedia we suggest extracting a *relation statement* for each hyperlink of Wikipedia from sentence surrounding hyperlink anchor of end concept in article text of start concept. For example for a hyperlink pointing from concept Music to concept Art one relation statement from article text of start concept Music is “Music is an art form whose medium is sound and silence.” (here hyperlink anchor underlined). We suggest that during exploration in hyperlink network of vocabulary when student traverses a hyperlink between concepts learning of this relationship is supported by showing to the student a relation statement corresponding to this hyperlink. Eventually a *learning session* consists of a chain of traversed hyperlinks and their relation statements that can be guided to proceed in a sequential process having tailored variation and repetition computed based on theory of spaced learning, as explained in our previous work in publication [P7] and discussed in Subchapter 12.1.

To enable implementing educational technology for practical educational activities for students we have carried out empirical experiments to try to identify some constraints of *conceptual scale-free small-world networks* and to better understand behavior of their properties. Thus besides developing a computational method for exploiting conceptual scale-free small-world networks to manage and explore educational material we now also report some preliminary findings of experiments about the properties of conceptual scale-free small-world networks that we have generated based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic.

Table 12.3 shows properties of *conceptual networks* that we have generated based on hyperlink network of the Wikipedia (as of June-July 2013) between concepts we retrieved from *English Vocabulary Profile* (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A) for cumulatively growing vocabularies corresponding to each of six language ability levels ranging from A1 to C2.

At the highest language ability level C2 we have the most extensive vocabulary that we call as vocabulary A1&A2&B1&B2&C1&C2 (i.e. including all six cumulative vocabularies of consecutive language ability levels A1, A2, B1, B2, C1 and C2 together) and we identified that it contains *15715 unique language items* (words or phrases) that include *3710 unique nouns*. Then we wanted to identify all possible hyperlinks that are connecting these 3710 unique nouns in hyperlink network of the Wikipedia and we found *25153 unique hyperlinks* so that they actually connected *2878 unique nouns* of these 3710 unique nouns. Appendix AC shows a full listing of all 25153 unique hyperlinks between 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns. Appendix AD shows for each vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed

separately for each language ability level. For each observed vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from A1 to A1&A2&B1&B2&C1&C2.

Table 12.3. Properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2.

Vocabulary of language ability level reached so far (predicted* = only extrapolated estimates)	Unique language items (words or phrases) in vocabulary	Unique nouns in vocabulary	Unique Wikipedia hyperlinks connecting unique nouns in vocabulary	Unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary
A1	785	305	1007	248 (A1: 248)
A1&A2	2382	880	3868	706 (A1: 265; A2: 441)
A1&A2&B1	5327	1761	9566	1374 (A1: 273; A2: 465; B1: 636)
A1&A2&B1&B2	9502	2707	17448	2121 (A1: 280; A2: 473; B1: 682; B2: 686)
A1&A2&B1&B2&C1	11908	3198	21410	2470 (A1: 281; A2: 479; B1: 694; B2: 701; C1: 315)
A1&A2&B1&B2&C1&C2	15715	3710	25153	2878 (A1: 283; A2: 483; B1: 706; B2: 718; C1: 328; C2: 360)
3000–5000 unique nouns (reasonable 95 percent level comprehension), predicted*	12900–21500 *	3000–5000 *	20308–33846 *	2308–3846 *
8000–9000 unique nouns (non-native adult), predicted*	34400–38700 *	8000–9000 *	54154–60923 *	6154–6923 *
20000 unique nouns (native adult), predicted*	86000 *	20000 *	135385 *	15385 *
54000 unique nouns (general vocabulary), predicted*	232200 *	54000 *	365538 *	41538 *

Therefore it seems that at language ability level C2 the Wikipedia can offer interconnected linkage for about 77.6 percent (2878/3710) of nouns belonging to current noun vocabulary. Furthermore, among these 2878 unique nouns 2635 occur as a start concept and 2310 occur as an end concept in connecting hyperlinks. According to our calculations each of these 2878 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 has an average value of 8.7 departing unique hyperlinks and a median value of 5 departing unique hyperlinks and an average value of 8.7 arriving unique hyperlinks and a median value of 5 arriving unique hyperlinks linking it to other unique nouns belonging to same vocabulary A1&A2&B1&B2&C1&C2. In the entity of 25153 unique hyperlinks it appeared that for 4824 hyperlinks there was another hyperlink going also into opposite direction thus 2412 connections can be considered bidirectional.

Since applying the hyperlink network of the Wikipedia for educational activities relies on those nouns that actually happen to exist in hyperlinks, we wanted to estimate the *properties of the conceptual networks* we have generated in respect to size of *noun vocabulary* that is actually available for browsing in the Wikipedia along unique hyperlinks connecting unique nouns of vocabulary.

By comparing growth of values in columns of Table 12.3 along language ability levels ranging from A1 to C2 we approximated that the number of unique nouns in vocabulary is about *1.3 times* the number of unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary, and the number of unique language items (words or phrases) in vocabulary is about *4.3 times* the number of unique nouns in vocabulary, and the number of unique Wikipedia hyperlinks connecting unique nouns in vocabulary is about *8.8 times* the number of unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary. Based on these dependencies we extrapolated to Table 12.3 coarse predicted estimated values to represent four additional cases in which the number of unique nouns in vocabulary reaches such language ability levels that have been suggested in previous research to correspond to reasonable *95 percent level comprehension* (3000–5000 or just 2000–3000 word families ((Nation & Waring 1997); (Laufer 1989))), *a non-native adult* (8000–9000 word families (Nation 2006)), *native adult* (20000 word families (Nation & Waring 1997)) and *general vocabulary* (well over 54000 word families in English (Nation & Waring 1997)).

Naturally vocabulary sizes for different language ability levels can be represented with various *alternative motivations and estimates*. As discussed earlier, Nation and Waring (1997) concluded based on earlier research by Laufer (1989) that about 95 percent coverage is sufficient for reasonable comprehension of text and can be reached especially in favourable tailored textual contexts with 3000–5000 word families or just 2000–3000 word families. As discussed earlier, however, Laufer and Ravenhorst-Kalakovski (2010) suggested that for independent reading comprehension second language learners should have a vocabulary of about 8000 words offering about 98 percent text coverage and for reading comprehension with some guidance and help they should have a vocabulary of about 4000–5000 words offering about 95 percent text coverage. In addition, it has been claimed that the vocabulary of a 5-year-old contains 4000–5000 word families for native English speakers (Nation & Waring 1997) and that

95-percent understanding of junior or senior high school English-for-second-language textbooks required about 3000–3200 highest-ranking lemmatized words of British National Corpus (Chujo 2004).

Brezina and Gablasova (2013) estimated that about 46 percent of 3000 highest-ranking words of British National Corpus are nouns ($0.46 \approx 1/2.2$) which is a greater ratio than a ratio based on our just mentioned approximation that there are 23 percent ($0.23 \approx 1/4.3$) unique nouns in unique vocabulary items of a vocabulary. Anyway since Wikipedia hyperlinks connect now only nouns we assume that a student's explorations among 2878 unique nouns in 25153 unique hyperlinks connecting unique nouns of vocabulary A1&A2&B1&B2&C1&C2 can at least indirectly offer a conceptual exposure and coverage of 2.2–4.3 times greater amount of unique language items (i.e. containing also other part-of-speech than just nouns) meaning coverage of 6261–12522 unique language items. A student can gain this additional exposure for example by reading supplementing words in relation statements extracted from sentences surrounding hyperlink anchor in article text of start concept.

Therefore we suggest that hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns with 25153 unique interconnecting hyperlinks can be considered to offer sufficient knowledge structure to represent relatively reliably *conceptualization of everyday human vocabulary* corresponding to reasonable 95 percent level comprehension (3000–5000 or just 2000–3000 word families ((Nation & Waring 1997); (Laufer 1989))) that is defined based on cumulative iterative collaborative building process of Wikipedia online encyclopedia.

In Table 12.3 when the number of unique nouns in vocabulary reaches such language ability levels that have been suggested in previous research to correspond to general vocabulary (well over 54000 word families in English (Nation & Waring 1997)), i.e. 54000 unique nouns, the extrapolated predicted estimates of Table 12.3 suggest 365538 unique Wikipedia hyperlinks connecting unique nouns in vocabulary and 41538 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary whereas based on Table 3.1 in the Wikipedia as of June 2013 having about 4.3 million articles there are about 1900000000 hyperlinks and about 590000 articles about common nouns (based on an estimated formula $0.138 \times (\text{number of articles})$ as explained in main text of Subchapter 3.8). Thus it seems that as of June 2013 the Wikipedia already contains about 5200 times more unique hyperlinks and about 14 times more unique nouns in unique hyperlinks than is required to cover general vocabulary according to our extrapolated predicted estimates. When observing evolution of the Wikipedia it turns out that already in July 2004 (when the Wikipedia was about 3.5 years old) there were about 305000 articles, containing estimated 42090 (0.138×305000) articles about common nouns, that is needed to correspond to 41538 unique nouns in unique Wikipedia hyperlinks required to cover general vocabulary according to our extrapolated predicted estimates.

It can be seen from Table 12.3 that when proceeding to a vocabulary that is one step bigger (for example from range of language ability levels A1–A2 to range of language ability levels A1–B1) the increasing Wikipedia linkage does not originate only from the latest difference in vocabulary levels (for example addition of level B1 concepts) but it

can partly originate also from concepts that belong to much earlier vocabulary (for example level A1 concepts and level A2 concepts) that emerge to Wikipedia linkage with a delay along with the latest vocabulary level (for example along addition of level B1 concepts).

Table 12.4 shows properties of *conceptual networks* that we have generated based on hyperlink network of the Wikipedia (as of June-July 2013) between concepts retrieved from *Oxford Wordlist* (<http://www.oxfordwordlist.com/pages/search.asp>) for vocabularies of each of five school levels ranging from Preparatory level to Year 4 level (as mentioned already earlier, when performing downloading the only setting we varied was school year, thus keeping settings concerning gender, language, indigenouness, school setting, location and text type always at option “any”, and furthermore nouns were extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile).

From Table 12.4 it can be seen that in vocabulary at the highest school level Year 4 we identified *1445 unique nouns* and when we wanted to identify all possible hyperlinks that are connecting these 1445 unique nouns in hyperlink network of the Wikipedia in June-July 2013 we found *6759 unique hyperlinks* so that they actually connected *1072 unique nouns* of these 1445 unique nouns. Furthermore, among these 1072 unique nouns 971 occur as a start concept and 898 occur as an end concept in connecting hyperlinks. Appendix AE shows for each vocabulary of school levels ranging from Preparatory to Year 4 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each school level (as mentioned earlier, nouns were extracted from Oxford Wordlist based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile). For each observed vocabulary ranging from Preparatory to Year 4 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from Preparatory to Year 4.

Table 12.4. Properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts for partially cumulative vocabularies of five school levels of Oxford Wordlist ranging from Preparatory to Year 4.

Vocabulary of school level reached so far	Unique language items (words or phrases) in vocabulary	Unique nouns in vocabulary	Unique Wikipedia hyperlinks connecting unique nouns in vocabulary	Unique nouns in Wikipedia hyperlinks connecting unique nouns in vocabulary
Preparatory	1923	685	2511	505 (Preparatory: 505)
Year 1	2364	811	2946	592 (Preparatory: 370; Year1: 592)
Year 2	3041	1008	4203	749 (Preparatory: 415; Year1: 460; Year2: 749)
Year 3	4808	1412	6750	1051 (Preparatory: 459; Year1: 520; Year2: 642; Year3: 1051)
Year 4	4949	1445	6759	1072 (Preparatory: 459; Year1: 512; Year2: 612; Year3: 825; Year4: 1072)

Therefore it seems that at school level Year 4 the Wikipedia can offer interconnected linkage for about 74.3 percent (1073/1445) of nouns belonging to current noun vocabulary. According to our calculations each of these 1073 interconnected nouns at school level Year 4 has an average value of 7.0 departing unique hyperlinks and a median value of 5 departing unique hyperlinks and an average value of 7.5 arriving unique hyperlinks and a median value of 5 arriving unique hyperlinks linking it to other nouns belonging to same Year 4 noun vocabulary. In the entity of 6759 unique hyperlinks for 1416 hyperlinks there was another hyperlink going into opposite direction thus 708 connections can be considered bidirectional.

It can be seen from Table 12.4 that when proceeding to a vocabulary that is one step bigger (for example from school level Year 1 to school level Year 2) the increasing Wikipedia linkage does not originate only from the latest difference in vocabulary levels (for example addition of level Year 2 concepts) but it can partly originate also from concepts that belong to much earlier vocabulary (for example level Preparatory concepts and level Year 1 concepts) that emerge to Wikipedia linkage with a delay along with the latest vocabulary level (for example along addition of level Year 2 concepts). Please note also, as mentioned earlier, that concepts of Oxford Wordlist and Wikipedia hyperlinks connecting unique nouns of Oxford Wordlist are only partially cumulative for consecutive language ability levels.

We carried out *random path explorations* in hyperlink network of 25153 unique hyperlinks connecting 2878 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 so that any hyperlink can be traversed in both actual linking direction and opposite direction and all explorations were started from concept Human (starting from concept

Human was motivated by our earlier finding that among 69 shared concepts in hyperlink network of the Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5). We reported initial findings in publication [P8] but later experiments indicated that those results were biased and gave too low numbers of visited concepts. Thus we report now here corrected results. A random path of 1000 steps visited 688 unique concepts (24 percent) of 2878 unique concepts and 50 percent of visits stayed among 202 unique concepts. Similarly a random path of 10000 steps visited 2025 unique concepts (70 percent) of 2878 unique concepts and 50 percent of visits stayed among 398 unique concepts, a random path of 100000 steps visited 2770 unique concepts (96 percent) of 2878 unique concepts and 50 percent of visits stayed among 454 unique concepts, and a random path of 1000000 steps visited 2850 unique concepts (99 percent) of 2878 unique concepts and 50 percent of visits stayed among 463 unique concepts. In fact it turned out that among 2878 unique concepts the biggest subentity that enabled traversing hyperlink chains between any of concepts belonging to this subentity in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 when any hyperlink can be traversed in both actual linking direction and opposite direction contained 2850 unique concepts (28 external unique concepts of 2878 unique concepts are shown in Appendix AD and corresponding 14 unique hyperlinks of 25153 unique interconnecting hyperlinks containing these 28 external unique concepts are shown in Appendix AC).

It thus appeared that random path explorations in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 have a tendency to visit more certain subsection of hyperlink network and with a closer inspection we identified that these more visited concepts seemed to have relatively high position in hierarchy of connectivity of concepts in hyperlink network. Some of the highest-ranking positions of the most visited concepts in a random path of 1000 steps were Government/Human (6 visits) and Dance/Tax/Water/Wheat (5 visits), in a random path of 10000 steps were Water (48 visits), Food (40 visits), Human (38 visits), Mammal (33 visits) and Animal/Law/Nutrition (30 visits), in a random path of 100000 steps were Human (426 visits), Water (410 visits), Food (297 visits), Animal (293 visits) and Philosophy (267 visits), and in a random path of 1000000 steps were Human (4404 visits), Water (3607 visits), Food (3037 visits), Animal (2765 visits) and Psychology (2604 visits). For 2878 unique nouns in 25153 unique hyperlinks connecting unique nouns of vocabulary A1&A2&B1&B2&C1&C2 Appendix AF shows the number of visits in a random path of 1000000 steps.

102 highest-ranking positions of the most visited concepts for 2878 unique nouns in 25153 unique hyperlinks connecting unique nouns of vocabulary A1&A2&B1&B2&C1&C2 in a random path of 1000000 steps (shown in Appendix AF) and 102 highest-ranking concepts in word lists generated by students (shown in Appendix F) share 30 concepts (29 percent) including: Animal, Biology, cloth/Clothing, Computer, Death, Disease, Education, Emotion, Evolution, Family, Food, God, Health, House, Human, Light, Money, Music, Nature, nutriment/Diet_(nutrition)/nutrition, Oxygen, Philosophy, Plant, Religion, Sea, Shoe, Sun, Time, War and Water. It was interesting to note that with a sufficiently large number of steps in random path

explorations concept Human gained highest number of visits and this seems to indicate that concept Human has a central role in defining conceptual connectivity of hyperlink network. When we generated additional random path explorations starting from also other concepts than just concept Human it turned out that concept Human still remained as one the most visited concepts. This central role of concept Human in random paths can be paralleled with further findings discussed in Subchapter 12.3 that concept Human is among the highest-ranking hyperlinked concepts of hyperlink network of vocabularies at the highest language ability levels of English Vocabulary Profile as shown in Table 12.5 and Table 12.9.

Just discussed results seem to indicate that in hyperlink network of vocabulary exploration relying heavily on random choices of student without systematic guidance can lead to relatively limited pedagogic gain due to visiting only limited subsection of all unique concepts and their unique connecting hyperlinks. Thus we suggest that pedagogically rewarding exploration in hyperlink network of vocabulary should actively exploit traversing the *shortest paths* connecting pairs of unique concepts of vocabulary. We think that in adoption of new knowledge the learner benefits from an opportunity to see intuitively the shortest connectivity between pieces of knowledge thus helping contextually to filter out less relevant things that might disturb concentration by excessive cognitive load, and using the shortest paths enables also highlighting clustering structure of conceptual relationships to the student and generating a systematic efficient process to traverse in hyperlink network of vocabulary with an extensive diverse coverage.

We suggest that to support adoption of vocabulary a student's guided exploration in hyperlink network of vocabulary could proceed pedagogically rewardingly if exploration of the shortest paths *gradually moves* to cover new concepts related to concepts that have been adopted already earlier. On coarser level of granularity this gradual moving can be implemented by moving from vocabulary A1 to A1&A2 and then from vocabulary A1&A2 to A1&A2&B1 and so on. On finer level of granularity the guided exploration should gradually introduce new concepts belonging to current vocabulary and its most related subset of concepts concerning current learning topic while still also helping to refresh previously adopted concepts, with sequential tailored variation and repetition computed based on theory of spaced learning as explained in publication [P7] and discussed in Subchapter 12.1.

We also suggest that these new concepts should particularly include highest-ranking concepts of the topics that are intended to be learned so that exploration in hyperlink network of vocabulary could be performed especially by traversing the *shortest paths between the highest-ranking concepts* of previously adopted concepts and highest-ranking concepts of new concepts. In addition we suggest that, when available, *parallel alternative shortest paths* should be traversed between pairs of concepts to learn better the diversity of conceptual relations. With these suggestions we expect to establish efficient connectivity covering old and new concepts relying on dominant concept clusters of hyperlink network shown to student and that could then be also easier to conceptualize by the student.

We suggest that according to the needs of the learner new cumulative sets of vocabularies along gradually increasing adoption of new knowledge can be gained by generating high-frequency word lists from suitable text samples concerning intended learning topic or for example retrieving a desired set of words from resources such as British National Corpus (Leech et al. 2001).

We analyzed a *sample of 102 Wikipedia articles* selected to match 102 highest-ranking terms in texts generated by students, here we used the set of 102 core concepts introduced in Subchapter 3.10 and listed in Table 3.4 with results shown in Appendix G. These 102 articles had together hyperlinks to 20512 end concepts of which 14907 were unique and an article had on average 201 (median value 152) departing hyperlinks (as of 3 March 2008). When analyzing all 422 unique hyperlinks existing between these 102 Wikipedia articles (as of 3 March 2008) we found out that each start concept of a hyperlink had on average 4.1 (median value 3.5) *different end concepts*. Furthermore among all hyperlinks between these 102 Wikipedia articles we identified that there were on average 1.5 (median value 1) *parallel hyperlinks* (i.e. a certain end concept having more than one hyperlink anchors in article text of start concept) from each start concept to its end concept. For example, an article having two departing unique hyperlinks will on average have one of these two unique hyperlinks duplicated ($1.5 \times 2 = 3$). In addition we identified that in all 422 unique hyperlinks existing between the set of 102 Wikipedia articles in the article text of start concept the end concept was mentioned on average 7.4 (median value 3) *different times*. On the other hand we identified that in the article text of each 102 articles on average 21.3 (median 20) *different concepts* corresponding to other 101 article titles were mentioned (i.e. resembling end concept).

Thus based on this sample of 102 articles it seems that when considering a noun vocabulary interconnected by Wikipedia hyperlinks, on average Wikipedia article has 1.5 hyperlink anchors for each hyperlink and the end concept of each hyperlink occurs 7.4 times in article text of start concept. Furthermore while about 4 percent ($4.1/101$) of concepts belonging to vocabulary can be actually reached via hyperlink from Wikipedia article it appears that about 21 percent ($21.3/101$) of concepts belonging to vocabulary are anyway mentioned in article text of an average Wikipedia article, meaning that number of potential relationships becomes multiplied with about 5 ($0.21/0.04$).

These results suggest that besides actually existing unique hyperlinks between concepts of a vocabulary and possible exploitation of parallel hyperlinks there exists a passive potential to extend current linking by establishing *additional supportive cross-linking* between all occurrences of concepts of vocabulary in all Wikipedia article texts of concepts of vocabulary²³. These findings suggest concerning vocabulary A1&A2&B1&B2&C1&C2 that hyperlink network which we so far managed to get to contain 2878 unique nouns with 25153 unique interconnecting hyperlinks can be extended progressively to contain much more hyperlinks, and using *multiplication*

²³ Please note that establishing this additional supportive cross-linking actually relies on feature that we described in Publication [P3] and Subchapter 6.2 as "*repetition of hyperlink terms*" when we described five features for ranking hyperlinks based on article statistics, and repetition of hyperlink terms denotes showing hyperlinks in a descending order of significance based on how many times the word (or group of words) forming the title of hyperlink's target article is mentioned in the current article, anywhere in its full textual content.

factors (1.5; 7.4 and 5) motivated above leads to an estimated range of 37730–186132 *hyperlinks*. By generating these supplementing hyperlinks we expect to increase diversity of linkage thus offering extended variation in exposure and coverage of a student's exploration in hyperlink network to adopt conceptual relationships and knowledge in general.

Although these compared values represent different temporal versions of the Wikipedia (from beginning of March 2008 and from June-July 2013) this comparison seems to indicate that even a relatively small collection of 102 *Wikipedia articles* can offer with its hyperlinks (14907 hyperlinks unique to collection of 102 observed core concepts) so large coverage of different hyperlinked concepts that this coverage somewhat approaches such levels of vocabulary that can be considered to represent *knowledge of a well-educated human* (language ability level A1–C2 containing 3710 nouns, connected with 25153 Wikipedia hyperlinks containing 2878 unique nouns).

We carried out experiments to identify how the shortest paths in hyperlink network of vocabulary evolve when observed vocabulary is cumulatively expanded thus introducing new interconnecting hyperlinks and intermediary concepts that enable *emergence of gradually shorter paths* between pairs of concepts of vocabulary as well as increase in the number of parallel alternative paths. We experimented with vocabularies ranging from vocabulary A1 with 1007 unique interconnecting hyperlinks to vocabulary A1&A2&B1&B2&C1&C2 with 25153 unique interconnecting hyperlinks and the results seemed to support suggested pedagogic gains of using the shortest paths to guide educational exploration for adoption of new knowledge. In our experiments to generate the shortest paths in hyperlink network showing them in decreasing order of length of the path and also showing all alternative parallel paths having equal length we used Yen's algorithm to compute top k shortest loopless paths with sufficiently high values of k (Yen 1971).

For example we analyzed how the *available shortest paths* evolve between start concept "question" and end concept "school" when expanding observed vocabulary cumulatively from A1 to A1&A2&B1&B2&C1&C2. With *vocabulary A1* the shortest paths require traversing eight consecutive hyperlinks and there is only one path of this length: question → problem → business → restaurant → food → supermarket → book → homework → school. With *vocabulary A1&A2* the length of the shortest path has decreased to three hyperlinks and again there is only one path of this length: question → quiz → game → school. With vocabularies bigger than A1&A2 the length of the shortest path does not anymore decrease from three hyperlinks but new alternative parallel paths emerge thus introducing diversity to express the characteristics of relationship of concepts (please note that those shortest paths found with smaller vocabularies remain available also with bigger vocabularies). With *vocabulary A1&A2&B1* two new alternative parallel paths emerge including question → grammar → education → school and question → information → education → school, and with *vocabulary A1&A2&B1&B2* five new paths include question → philosophy → psychology → school, question → philosophy → government → school, question → theory → education → school, question → theory → psychology → school and question → concept → psychology → school. With *vocabulary A1&A2&B1&B2&C1*

one new alternative parallel path emerges including question → proposition → psychology → school but *vocabulary A1&A2&B1&B2&C1&C2* does not introduce any more new paths (i.e. *vocabulary A1&A2&B1&B2&C1&C2* offers nine parallel paths) which can possibly even indicate that already with this size of vocabulary some kind of saturation has been reached in formation of somewhat optimal connectivity between these two concepts of human knowledge in respect to the shortness of paths and diversity of parallel paths.

12.3. Estimated properties of explorations based on cumulative vocabularies and conceptual networks

We have now explained our experiments creating estimates about the sizes of hyperlink networks that can match with language ability levels from A1 to C2 of English Vocabulary Profile, and also estimates about the sizes of hyperlink networks that can match with sizes of vocabularies covering language usage needs for reasonable 95 percent level comprehension, non-native adults, native adults and general vocabulary. We have also estimated how already hyperlink network of vocabulary *A1&A2&B1&B2&C1&C2* containing 2878 unique nouns with 25153 unique interconnecting hyperlinks can be extended to offer much more hyperlinks based on article texts defining unused potential conceptual relationships and possible exploitation of parallel hyperlinks. We have also experimentally identified very limited coverage gained with random paths in hyperlink network of vocabulary and thus we have suggested using the shortest paths to guide educational exploration for adoption of new knowledge, and with cumulatively growing vocabularies the length of shortest paths can usefully decrease and alternative parallel paths offering diversity can be gained. We do not know any previous research proposing same kind of approach and results that we have presented here and we hope that our suggestions can open promising new perspectives to learning. Based on our experiments and analysis in publication [P8] we next explain some further *suggestions for educational use* of hyperlink network of vocabulary and we hope these ideas can offer inspiration for future work in both on research agenda and in real-life application to support personalized learning.

It is pedagogically useful that when observing the shortest paths to two *opposite directions* between a pair of concepts there often emerges two *different routings* offering new perspectives. For example with vocabulary *A1&A2&B1&B2&C1&C2* from concept “love” to concept “memory” the shortest paths have two hyperlinks and there is only one path of this length: love → psychology → memory, and from concept “memory” to concept “love” the shortest paths have three hyperlinks and there are three alternative parallel paths of this length including memory → psychology → emotion → love, memory → psychology → motivation → love and memory → learning → emotion → love. Besides identifying the shortest paths in both directions between a pair of concept we suggest that additional pedagogic potential of diversity and possibly even shorter paths become available when identifying the shortest paths in hyperlink network of vocabulary also so that any hyperlink can be traversed in both actual linking

direction and opposite direction. When enabling these *bidirectional hyperlink traversals* in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2, from concept “love” to concept “memory” the shortest paths have length of two hyperlinks and there are three alternative parallel paths of this length: love → psychology → memory, love → loneliness → memory and love → mind → memory.

We think that pedagogically useful exploration in hyperlink network of vocabulary could benefit from exploring especially those shortest paths that exist between the *highest-ranking hyperlinked concepts* and *strongly rising hyperlinked concepts* of vocabulary. Therefore we have generated some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2 as shown in Tables 12.5–12.9.

Table 12.5 offers an overview showing some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* and six cumulative vocabularies of *English Vocabulary Profile* so that in this table occurrences as start concepts and end concepts are analyzed together in *joint form* (i.e. occurrences as start/end concept). Table 12.6 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* when considering for each school level *only new concepts* (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary), and in this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately. Table 12.7 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for six cumulative vocabularies of *English Vocabulary Profile* when considering for each language ability level *only new concepts* (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary), and in this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately. Table 12.8 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for five partially cumulative vocabularies of *Oxford Wordlist* so that in this table occurrences as start concepts and end concepts are analyzed separately. Table 12.9 shows some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for six cumulative vocabularies of *English Vocabulary Profile* so that in this table occurrences as start concepts and end concepts are analyzed separately.

Column “High” in Tables 12.5–12.9 lists some of the *highest-ranking hyperlinked concepts* (occurrences indicated in parenthesis), i.e. those concepts that have the highest number of unique departing hyperlinks (in case of highest-ranking as being a start concept) or the highest number of unique arriving hyperlinks (in case of highest-ranking as being end concept). Please note that while observing either only departing hyperlinks or only arriving hyperlinks we express number of only unique hyperlinks (either departing hyperlinks or arriving hyperlinks), then when observing number of departing/arriving hyperlinks we express number of hyperlinks that is just a sum of

unique departing and unique arriving hyperlinks and therefore can contain overlap and thus in many cases is not number of only unique departing/arriving hyperlinks. This means in Tables 12.5–12.7 that the number of occurrences as start/end concept can contain at most two references to same hyperlinked concept, once as start concept of arriving hyperlink and once as end concept of departing hyperlink.

Column “Rising” in Tables 12.5–12.9 lists some of *strongly rising hyperlinked concepts*, i.e. concepts that seem to strongly rise in ranking position from previous smaller vocabulary to current bigger vocabulary in respect to the number of departing or arriving hyperlinks (for example which of the concepts belonging to vocabulary A1 seem to get among the biggest increase in ranking position when observing these same concepts again in vocabulary A1&A2). We created shown list of rising concepts (change in ranking position indicated in parenthesis, suffix -s indicating shared ranking position) by browsing highest-ranking concepts in decreasing order and selected such concepts which increased their ranking position by at least value 0.01 when for all vocabularies the ranges of ranking values had been first transformed to an equal range of closed interval [0,1].²⁴

²⁴ It should be noted that when observing vocabularies consecutively going from smaller vocabulary to bigger vocabulary there emerges a greater range of ranking values also when transformed to equal range of closed interval [0,1] and ranking values are not directly comparable per se (thus even if a concept gets a ranking value that is greater number seeming to indicate being now lower in ranking position it is possible that relatively the ranking position has in fact become higher). Anyway we have aimed to take into account relative rankings so that when comparing ranking positions and their change between various ranking value ranges distortion should be minimized in this analysis.

Table 12.5. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 and cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2. In this table occurrences as start concepts and end concepts are analyzed together in joint form (i.e. occurrences as start/end concept).

Oxford Wordlist: Preparatory, as start/end concept		Oxford Wordlist: Year 1, as start/end concept		Oxford Wordlist: Year 2, as start/end concept		Oxford Wordlist: Year 3, as start/end concept		Oxford Wordlist: Year 4, as start/end concept			
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising		
water (69)	N/A	water (71)	milk (30->7)	water (84)	light (25.5s->13.5s)	water (111)	fruit (15->7.5s)	water (113)	skin (44->29.5s)		
animal (57)	N/A	food (65)	red; tiger (21.5s->15.5s)	human (79)	wood (19.5s->13.5s)	human (104)	music (61.5s->25.5s)	human (111)	grass (51->33)		
food (55)	N/A	animal (61)	sheep (58->19.5s)	animal; food (73)	science (78->18.5s)	food (90)	road (72.5s->29.5s)	food (85)	house (55->37.5s)		
bird (45)	N/A	bird (51)	day (39.5s->19.5s)	insect (55)	bread (25.5s->18.5s)	animal (80)	mind (35.5s->29.5s)	animal (79)	life (92.5s->42)		
earth (40)	N/A	fish (47)	meal (25->22.5s)	earth (53)	bat (29->24.5s)	earth (77)	butter (53->36)	earth (78)	fear (83->47.5s)		
fish; sun (38)	N/A	earth (46)	family (66.5s->25.5s)	bird (52)	dog (25.5s->24.5s)	fruit; meat; oxygen; sun (62)	rain; sausage (43->36)	transport (63)	shoe (67.5s->47.5s)		
fruit (37)	N/A	milk (39)	bread (30->25.5s)	fish (50)	art (58->31)	fish (61)	skin (72.5s->44)	plant; sun (62)	bone (61->47.5s)		
wood (34)	N/A	time (37)	bat (39.5s->29)	meat (46)	paper (49->35.5s)	bird; plant (60)	seed (67->44)	energy (60)	door (113->54)		
time (33)	N/A	nature (36)	cheese; year (88.5s->34.5s)	plant (44)	ocean (42->35.5s)	transport (55)	sky; snow (61.5s->44)	bird (59)	death (83->54)		
light; meat; plant; wind (30)	N/A	meat; turkey (35)	soup (46.5s->34.5s)	time (43)	fire (78->43)	time (54)	kitchen (53->44)	entertainment; fruit; nature (58)	gas (132.5s->62)		
English Vocabulary Profile: A1, as start/end concept		English Vocabulary Profile: A1-A2, as start/end concept		English Vocabulary Profile: A1-B1, as start/end concept		English Vocabulary Profile: A1-B2, as start/end concept		English Vocabulary Profile: A1-C1, as start/end concept		English Vocabulary Profile: A1-C2, as start/end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (39)	N/A	water (81)	fruit (6.5s->3)	human (129)	science (38->6.5s)	human (188)	law (47.5s->26.5s)	human (209)	life (71.5s->51.5s)	human (227)	god (80->57)
water (34)	N/A	food (72)	animal (11->4)	water (122)	physics (20.5s->18.5s)	water (165)	business (47.5s->32.5s)	water (184)	emotion (86.5s->75.5s)	water (191)	emotion (75.5s->57)
month (33)	N/A	fruit (49)	time (13->5)	food (105)	art (31->21.5s)	food (133)	government (97.5s->41)	food (144)	death (96->85)	food (158)	death (85->61)
plant (26)	N/A	animal (43)	meat (14.5->7)	earth (78)	insect (20.5s->21.5s)	earth (113)	crime (146->44.5s)	mammal (129)	genetics (146->90)	mammal (137)	reality (100->75)
day; fruit; supermarket; year (25)	N/A	time (42)	sun (35.5s->9)	entertainment (74)	wind (25->31)	science (104)	chemistry (65.5s->44.5s)	earth (127)	health (122.5s->95)	earth; psychology (134)	reason (90->75)
bread; milk (24)	N/A	plant (41)	supermarket (6.5s->9)	science; time (73)	language (95->35.5s)	animal (101)	medicine (80->49)	science (118)	blood (103.5s->95)	philosophy (132)	politics (95->78.5s)
animal (23)	N/A	meat (40)	milk (9.5s->12)	transport (72)	film (51->35.5s)	philosophy (100)	history (47.5s->51.5s)	animal (117)	horse (109->100)	science (130)	horse (100->87.5s)
meal (22)	N/A	month; sun; supermarket (39)	bird (35.5s->15)	animal; fruit (71)	fish (31->35.5)	psychology (99)	knowledge (158->54)	philosophy (116)	trade (193.5s->105.5s)	animal (127)	war (165->93)
time (21)	N/A	milk; nature; toy (37)	music (28->15)	plant (69)	painting (42.5s->39)	culture (98)	money (97.5s->56.5s)	psychology (112)	bone (122.5s->116)	evolution (119)	civilization (122->99.5s)
meat; soup (19)	N/A	bird; bread; music (36)	bread (9.5s->15)	education (66)	temperature (42.5s->42)	carbon dioxide (97)	biology (72->56.5s)	evolution (109)	civilization; metal (133->122)	culture (118)	bone (116->99.5s)

Table 12.6. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4 when considering for each language ability level only new concepts (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary). In this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately.

Oxford Wordlist: Preparatory, new	Oxford Wordlist: Year 1, new	Oxford Wordlist: Year 2, new	Oxford Wordlist: Year 3, new	Oxford Wordlist: Year 4, new
<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>	<i>as start/end concept</i>
water (69)	nature (36)	human (79)	oxygen (62)	nature; entertainment (58)
animal (57)	turkey (35)	insect (55)	transport (55)	technology (49)
food (55)	butter (32)	plant (44)	iron; energy (53)	copper; cattle (45)
bird (45)	tool; goat (25)	wind (35)	species (48)	temperature; liquid (41)
earth (40)	god (24)	culture (32)	plastic; clothing (42)	steel (39)
fish; sun (38)	vegetable (23)	shoe (31)	supermarket; sunlight (40)	leaf (31)
fruit (37)	rainforest; painting; cooking (22)	mind (30)	soil (39)	goat (30)
wood (34)	money; life (21)	sausage; bone (29)	vegetable; muscle (38)	rainforest; pressure; coast (29)
time (33)	leaf; father (20)	kitchen (28)	weather; sugar (34)	society; gardening; fuel (25)
light; meat; plant; wind (30)	beef (19)	death (27)	television; taste; fear (32)	concrete (24)

Oxford Wordlist: Preparatory, new		Oxford Wordlist: Year 1, new		Oxford Wordlist: Year 2, new		Oxford Wordlist: Year 3, new		Oxford Wordlist: Year 4, new	
as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept
food (29)	animal (54)	nature (24)	turkey (33)	human (32)	human (47)	transport (39)	oxygen; iron (39)	entertainment (43)	copper (39)
water (27)	water (42)	painting; butter (16)	god (19)	shoe (27)	insect (33)	supermarket (27)	species (38)	nature (42)	temperature (34)
toy (25)	earth (33)	rainforest (15)	cooking; butter (16)	kitchen (23)	culture (24)	clothing (25)	plastic (34)	technology (30)	liquid (27)
shoe (22)	fish (32)	father (14)	wool; goat; baseball (15)	insect (22)	plant (23)	oxygen (23)	energy (31)	rainforest; cattle (21)	steel (26)
tiger; sky (20)	wood (30)	vegetable; tool (13)	money; life (14)	plant (21)	lead; heat (20)	energy (22)	soil (30)	gardening; coast (19)	cattle (24)
time; wind; red (19)	bird (29)	taste (12)	business (13)	wind; mind (20)	rice; bone (19)	title (21)	sugar (29)	emergency (17)	pressure (23)
meal; pet; game (18)	sun (27)	recycling; mask; lawn (11)	tool; nature; beef (12)	sausage (19)	radio (18)	vegetable; taste (20)	television (27)	goat (16)	society (20)
soup; party (17)	food (26)	leaf; goat; gift (10)	glass; crime; cotton (11)	skin; future; flight (17)	salt; disease; air (17)	scientist; reason; perfume; mixture; health; artist (19)	muscle (25)	parrot; leaf (15)	wool; technology (19)
bird; plant; blue; bread; bat; garden (16)	fruit (23)	skull; reason (9)	vegetable; season; potato; leaf; camel (10)	month; hobby (15)	history; fuel (16)	fear (18)	law (24)	scissors; liquid (14)	concrete (18)
meat; grass; sea; road; kitchen (15)	horse (22)	season; november; eye (8)	silver; fur; coffee (9)	force; cloud; banana (14)	wind; cancer (15)	sunlight; sense; mat (17)	sunlight (23)	steel; pear; glove (13)	nature; leaf; fuel; acid (16)

Table 12.7. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2 when considering for each language ability level only new concepts (i.e. such concepts that did not belong to previous smaller vocabulary but belong to current bigger vocabulary). In this table occurrences as start concepts and end concepts are analyzed both together in joint form (i.e. occurrences as start/end concept) and separately.

English Vocabulary Profile: A1, new	English Vocabulary Profile: A1–A2, new	English Vocabulary Profile: A1–B1, new	English Vocabulary Profile: A1–B2, new	English Vocabulary Profile: A1–C1, new	English Vocabulary Profile: A1–C2, new
as start/end concept	as start/end concept	as start/end concept	as start/end concept	as start/end concept	as start/end concept
food (39)	toy; nature (37)	human (129)	philosophy (100)	mammal (129)	dna (73)
water (34)	physics; light; insect (34)	earth (78)	psychology (99)	protein; bacteria (93)	sustainability (63)
month (33)	wood; leather (32)	entertainment (74)	carbon dioxide (97)	globalization (89)	conscience (62)
plant (26)	red; art (31)	transport (72)	oxygen; agriculture (92)	infrastructure (86)	virtue (61)
day; fruit; supermarket; year (25)	science; plastic (30)	education (66)	evolution (86)	nutrition (80)	immune system (59)
bread; milk (24)	temperature; salad; painting (29)	culture (63)	clothing (79)	extinction (62)	capitalism (57)
animal (23)	cooking (27)	technology (62)	carbon (75)	ecology (59)	perception (55)
meal (22)	sausage; chicken (26)	religion (58)	species (74)	archaeology (58)	astronomy (54)
time (21)	yellow; sound; health (24)	turkey; economics (54)	steel; copper (64)	density (56)	hierarchy (52)
meat; soup (19)	yogurt; ship; mail; blue (23)	mind; energy; cattle (52)	advertising (60)	perfection; gene (52)	famine (51)

English Vocabulary Profile: A1, new		English Vocabulary Profile: A1–A2, new		English Vocabulary Profile: A1–B1, new		English Vocabulary Profile: A1–B2, new		English Vocabulary Profile: A1–C1, new		English Vocabulary Profile: A1–C2, new	
as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept	as start concept	as end concept
food (22)	animal (21)	toy (30)	wood (32)	human (61)	human (68)	insurance; carbon (43)	carbon dioxide (70)	infrastructure (64)	mammal (91)	conscience (55)	dna (51)
month (19)	water (20)	nature (27)	leather (24)	entertainment (57)	earth (62)	clothing (41)	philosophy (69)	nutrition (63)	protein (81)	sustainability (47)	perception (37)
supermarket; party (18)	food (17)	red; painting (22)	temperature; plastic; light (23)	transport (50)	turkey (53)	reputation (38)	psychology (65)	globalization (58)	bacteria (65)	hierarchy; analogy (35)	astronomy (33)
plant; bread; meal (16)	fish; rice (16)	sky; salad (20)	insect (22)	technology; mind (35)	religion (42)	reality (36)	species; oxygen (60)	perfection (50)	gene (35)	famine; burial (34)	immune system (31)
soup (15)	day; year; milk (15)	hobby (18)	science; cooking (21)	scientist (29)	culture (41)	psychology (34)	agriculture (59)	mammal; loneliness (38)	reptile; density (34)	virtue (33)	artificial intelligence (30)
water; house (14)	month; fruit (14)	sausage; camping (17)	art (20)	education; cattle (26)	education (40)	theory; suffering; agriculture; abuse (33)	evolution (56)	ecology (32)	extinction; archaeology (33)	produce; immune system; capitalism (28)	capitalism (29)
lunch (12)	sugar; sun (13)	yellow; pink; physics; curry; blue; bat (16)	wool (19)	coast (25)	iron; economics (39)	oxygen; institution; economy (32)	copper (54)	evaluation (31)	logic (32)	narrative (25)	virtue (28)
fruit; time; garden; shoe (11)	meat (12)	ship; mail; health; artist; airport (15)	physics (18)	translation; tiger; future (24)	energy (35)	philosophy (31)	god (45)	innovation; extinction (29)	globalization (31)	propaganda (23)	crystal (24)
day; year; book; drink; november; game (10)	cheese; tea; sheep (11)	perfume; competition (14)	biology (17)	writer (23)	law (34)	evolution (30)	steel (42)	bacteria (28)	coal (29)	wilderness; drought; dna; ambiguity (22)	sin; narrative; infant (23)
milk; grass; tomato (9)	plant; time; bird; horse; television; computer (10)	sound; omelette; glove; cloud; chicken; bottle (13)	baseball (16)	title; taste; culture (22)	literature (32)	community; carbon dioxide; aluminium (27)	soil (39)	leadership; digestion; archaeology (25)	erosion (28)	intellectual; astronomy (21)	ritual; metaphor (22)

Table 12.8. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for partially cumulative vocabularies of five language ability levels of Oxford Wordlist ranging from Preparatory to Year 4. In this table occurrences as start concepts and end concepts are analyzed separately.

Oxford Wordlist: Preparatory				Oxford Wordlist: Year 1				Oxford Wordlist: Year 2			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (29)	N/A	animal (54)	N/A	food (34)	game (12.5s->6)	animal (58)	sheep (16.5s->12)	food (38)	meat (19.5s->6)	animal (68)	science (25.5->12)
water (27)	N/A	water (42)	N/A	water (30)	bat (19->9)	water (41)	meat (19->15.5s)	water; human (32)	sky (13->7)	water (52)	light (17->13.5s)
toy (25)	N/A	earth (33)	N/A	toy (25)	camping (30->14)	fish (40)	cheese (46.5s->19.5s)	toy (28)	chicken (42->31)	human (47)	art (42->24.5s)
shoe (22)	N/A	fish (32)	N/A	nature (24)	farm (58->19.5s)	earth (38)	time (24->19.5s)	shoe (27)	desert; house (34.5s->31s)	earth (42)	dog (34.5s->28)
tiger; sky (20)	N/A	wood (30)	N/A	tiger (23)	salad (39.5s->25.5s)	bird (35)	computer (58->22.5s)	meat; sky (25)	gardening; white (49->35.5s)	fish (40)	fat (58->31)
time; wind; red (19)	N/A	bird (29)	N/A	game (22)	milk (122->29)	turkey (33)	day (39.5s->25.5s)	bat (24)	bed (34.5->35.5)	wood (38)	life (34.5s->31)
meal; pet; game (18)	N/A	sun (27)	N/A	red (21)	day (39.5->29)	food (31)	grass (30->25.5s)	tiger; kitchen (23)	light (97->43)	turkey (37)	fire (49->35.5s)
soup; party (17)	N/A	food (26)	N/A	time; bat (20)	ship (30->29)	wood (27)	gold (75.5s->29)	insect; time; soup (22)	door; ocean; shark (58->43)	food (35)	metal (179->43)
bird; plant; blue; bread; bat; garden (16)	N/A	fruit (23)	N/A	meal; soup (19)	yellow (46.5s->34.5s)	milk; sun (25)	family (58->34.5)	plant; red; pet; game (21)	blue (49->43)	insect; bird (33)	lake (68->43)
meat; grass; sea; road; kitchen (15)	N/A	horse (22)	N/A	pet; sky; camping (18)	desert (39.5s->34.5s)	fruit; sheep; horse (21)	sport (51->34.5s)	bread; wind; mind; painting; party (20)	drink (97->53)	sun (31)	war (42->43)
Oxford Wordlist: Year 3				Oxford Wordlist: Year 4							
As start concept		As end concept		As start concept		As end concept					
High	Rising	High	Rising	High	Rising	High	Rising				
food (52)	red (15->7.5s)	animal (73)	fat (31->21)	human (53)	door (36->22.5s)	animal (73)	war (44->22.5s)				
water; human (48)	plant (13.5s->7.5s)	water (63)	music (43->29.5s)	food (48)	fear (73.5s->31)	water (67)	life (61->37.5s)				
transport (39)	sausage (24.5s->13)	earth (61)	wind (53->36)	water (46)	sound; garden (61->33)	earth (62)	clothing (73.5s->42)				
meat (35)	sea (24.5s->17.5s)	human (56)	snow (61.5s->44)	transport (45)	competition (67.5s->37.5s)	human (58)	gas (122.5s->47.5s)				
toy (34)	fruit (72.5s->20)	fish (46)	computer; disease; planet; salt; war (43->44)	entertainment (43)	machine (61->37.5s)	sun; fish (44)	government; heart (61->47.5s)				
sky (33)	road (43->25.5s)	wood (44)	cancer; rain (53->51)	nature (42)	perfume (67.5s->42)	bird (43)	pain (132.5s->54)				
plant; red (31)	skin (31->25.5s)	sun (43)	tree (53->55)	shoe (34)	cloud (55->42)	wood (41)	brain; medicine; river (83->62)				
shoe (30)	house (31->29.5s)	bird (42)	heart (72.5s->61)	toy (33)	blue (61->47.5)	copper (39)	blood; flower (73.5s->62)				
kitchen (29)	pizza (43->31.5s)	oxygen; iron (39)	butter (61.5s->61)	red (32)	death; hunting (83->54)	species (38)	baseball; grass; transport (92.5s->71.5s)				
time; sausage; soup (28)	ship (31->31.5s)	food; species (38)	glass; bread (53->61)	technology; sky (30)	day (73.5->54)	food (37)	ocean (92.5s->76.5s)				

Table 12.9. Some of the highest-ranking hyperlinked concepts and strongly rising hyperlinked concepts for cumulative vocabularies of six language ability levels of English Vocabulary Profile ranging from A1 to C2. In this table occurrences as start concepts and end concepts are analyzed separately.

English Vocabulary Profile: A1				English Vocabulary Profile: A1–A2				English Vocabulary Profile: A1–B1			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
food (22)	N/A	animal (21)	N/A	food (38)	water (9.5s ->2)	water (48)	sun (11.5s ->5.5s)	human (61)	time (12 ->7)	human (68)	science (20->6)
month (19)	N/A	water (20)	N/A	water (33)	shoe (13.5s ->5)	animal (41)	fruit (9.5s ->5.5s)	food (60)	book (15.5s- >14)	animal (67)	music (32 ->18.5s)
supermarket; party (18)	N/A	food (17)	N/A	toy (30)	game (18.5s ->7.5s)	food (34)	television (19.5s ->7.5s)	entertainment (57)	painting; kitchen (15.5s ->15.5s)	water (66)	plant (32 ->22.5s)
plant; bread; meal (16)	N/A	fish; rice (16)	N/A	supermarket; nature; shoe (27)	soup (8 ->7.5s)	wood (32)	sugar (11.5s ->7.5s)	water (56)	fruit (20.5s ->17.5s)	earth (62)	art (22 ->22.5s)
soup (15)	N/A	day; year; milk (15)	N/A	soup; game (25)	bread (6 ->9.5s)	fruit; sun (29)	bird (19.5s ->9)	transport (50)	artist (46.5s ->21.5s)	turkey (53)	business (36.5s ->28.5s)
water; house (14)	N/A	month; fruit (14)	N/A	month; bread (24)	time (13.5s ->12)	sugar; television (26)	meat (13 ->11.5s)	nature (46)	sausage (30- >21.5s)	science (49)	computer (41 ->31.5s)
lunch (12)	N/A	sugar; sun (13)	N/A	time; plant; party (23)	kitchen (40 ->15.5s)	bird (25)	milk (7 ->11.5s)	time (41)	sky; wind (20.5s ->21.5s)	food (45)	time (26 ->31.5s)
fruit; time; garden; shoe (11)	N/A	meat (12)	N/A	book; red; kitchen; painting (22)	book (18.5s ->15.5s)	meat; milk; leather; fish (24)	paper (31 ->20)	shoe (40)	pizza (26 ->26.5s)	wood (44)	history (78.5s ->34.5s)
day; year; book; drink; november; game (10)	N/A	cheese; tea; sheep (11)	N/A	meal (21)	wind (54.5s ->20.5s)	light; plastic; temperature; rice (23)	radio (49.5s ->26)	soup; toy (37)	sea (63.5s ->30)	sun (43)	physics (32 ->34.5s)
milk; grass; tomato (9)	N/A	plant; time; bird; horse; television; computer (10)	N/A	fruit; wind; salad; sky (20)	fruit (13.5 ->20.5s)	insect (22)	wine (31 ->26)	technology; mind (35)	meat (36.5s- >30)	religion (42)	language (66 ->40)
English Vocabulary Profile: A1–B2				English Vocabulary Profile: A1–C1				English Vocabulary Profile: A1–C2			
As start concept		As end concept		As start concept		As end concept		As start concept		As end concept	
High	Rising	High	Rising	High	Rising	High	Rising	High	Rising	High	Rising
human (98)	competition; science (48.5s ->18.5s)	water (93)	law (26.5s ->10.5s)	human (112)	abuse (50 ->21)	water (102)	genetics (65 ->50)	human (121)	philosophy (74- >44)	animal (108)	war (65.5s ->41)
food (78)	meat (30 ->18.5s)	animal (91)	government (50.5s ->25.5s)	food (86)	evolution (69->38)	animal (100)	medicine (70.5s- ->53)	food (93)	cancer (80 ->58)	human; water (106)	logic (116 ->82.5s)
water (72)	reason (56.5s ->24)	human (90)	language (40 ->34.5s)	water (82)	oxygen (56 ->39)	human (97)	crime (84 ->59.5s)	water (85)	ship (94 ->70)	earth (101)	death (127 ->88)
entertainment (68)	crime (93 ->30.5s)	earth (84)	biology (44.5s ->40)	nature (75)	life (124 ->43)	earth (94)	statistics (90 ->65.5s)	nature (79)	death (92 ->74)	mammal (98)	police (127 ->95)
transport (66)	future (48.5s ->30.5s)	carbon dioxide (70)	chemistry (50.5s ->47)	entertainment (71)	title (77.5 ->64)	mammal (91)	aluminium (95.5s- ->84)	entertainment (74)	evaluation (100- ->81)	psychology (92)	profession (108 ->95)
nature (65)	music (37.5s ->34)	philosophy; turkey (69)	disease (65.5s ->51.5s)	transport (70)	rainforest (91.5s- ->67)	philosophy (83)	experiment (117- ->93.5s)	transport (72)	invasion (117- ->82)	philosophy (90)	contract (168 ->112)
mind (52)	culture (65- >44)	religion (68)	technology (50.5s ->51.5s)	infrastructure (64)	bird (124 ->79)	protein (81)	blood (108 ->93.5s)	nutrition (68)	creativity (109- ->87)	law (86)	climate change (148 ->112)
technology (48)	skin (80 ->50)	psychology (65)	society (56 ->55.5s)	nutrition (63)	cancer (143.5s ->80)	religion (78)	child; heart (108- ->101)	mind (66)	civilization (155- ->100)	protein; religion (85)	system (138 ->112)
time; shoe (47)	insect (65- ->50)	culture; law (64)	knowledge; war (109.5s ->59.5s)	globalization; mind (58)	milk (91.5s ->81)	psychology; carbon dioxide (76)	trade (158 ->108)	infrastructure (65)	mask (133 ->112)	science; carbon dioxide (80)	fear (168-> 121.5s)
plant (45)	garden; writer (56.5s ->61.5s)	science (63)	money (99.5s ->65)	shoe (54)	death (143.5s ->92)	turkey (75)	risk; tool (139.5s- ->116)	globalization (63)	cloud (127 ->119)	turkey (79)	mind (157.5s ->121.5s)

We think that a person's ability to adopt new knowledge based on the shortest paths between concepts is affected for example by the *length of the shortest paths*, the number of *alternative parallel shortest paths* and the number of different concepts belonging to *intermediary concepts* along paths. We think that among parallel paths those shortest paths that have highest number of shared intermediary concepts and especially such intermediary concepts that occur most often among paths are important paths to define meaning of relationship between a pair of concepts. On the other hand to express diversity of meanings those shortest paths are important which have *most distinctive routing* among parallel paths (i.e. minimizing sharing of concepts). Also longer paths than the shortest paths can complement meanings of conceptual relationships. We think that to adopt new knowledge a successful pedagogical exploration in hyperlink network of vocabulary could possibly benefit from such mental processes of student that have resemblance to traversing *average search paths* in network. Thus we suggest that conceptualization in the student's mind could benefit from having such guided exploration in conceptual networks that enables many explorations that do not explore directly only the shortest paths between concepts but instead extend to cover also some *sidetracks* and even *dead-ends*.

Motivated by previous research showing that in a small-world network of 10000 nodes has an average search path of 950 steps for average degree of 10 and average search path of 200 steps for average degree of 30 (Rodero-Merino et al. 2010) and that Wikipedia has mean out-degree 20.63 (median value 12) (Kamps & Koolen 2009), we thus coarsely estimate that *in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2* having average out-degree 8.7 (median value 5) and containing 2878 unique nouns to enable the student to at least weakly *conceptualize a single relationship* between a pair of concepts could possibly require exploring about *300 steps* in the hyperlink network of vocabulary. Since previous research showed that in the Wikipedia on average 4.573 hyperlink steps are between a pair of concepts (Dolan 2011), and similarly in Facebook social network the average number of relationship steps between two users is 4.74 (Backstrom et al. 2011), our coarse estimate of exploring 300 steps is about *66 times the average length of the shortest path* between a pair of concepts in hyperlink network of vocabulary.

It thus seems that the student's conceptualization of conceptual relationships can require many times more exploration steps in the hyperlink network than belong to exploring just the shortest paths. On the other hand, it is possible that when traversing one exploration path several concepts that become encountered along the path can be cumulatively conceptualized in parallel, and it is also possible that the number of steps needed in later explorations can decrease as some kind of memories about previous explorations help to guide later explorations.

Since earlier research estimates that children are daily exposed to hear about 12815 words (Gilkerson & Richards 2009) and produce 1000–2700 vocalizations (Gilkerson & Richards 2009), and adults speak daily about 15669–16215 words (Mehl et al. 2007), it seems to us that human learning ability apparently can easily manage knowledge adoption at least through listening at a daily rate of about 12815–16215 words. Based on earlier research it seems that *knowledge adoption through reading* can have

somewhat lower levels than listening but still managing daily rate of about *1647–12967 words* (Anderson et al. 1988) corresponding with an average length of 20 words in sentence (DuBay 2004) to reading 80–648 sentences which can take with a suggested reading speed 200 words per minute (Lewandowski et al. 2003) about 8–65 minutes. Motivated by these estimates we concluded based on earlier research, we suggest that adoption of vocabulary by *exploration in hyperlink network* of vocabulary can be usefully carried out in a daily process that resembles reading *80–648 sentences*.

Since each hyperlink in the Wikipedia typically has its own sentence (in article text surrounding hyperlink anchor) defining the relationship between start concept and end concept, and since the shortest path between a pair of concepts has on average 4.573 hyperlink steps in the Wikipedia (Dolan 2011), knowledge adoption of *80–648 sentences per day* can be considered to correspond to traversing shortest paths of about *17–142 average pairs of concepts* in hyperlink network of vocabulary. Based on previous recommendations of about 3–4 spaced exposures to enable fertile learning ((Thalheimer 2006); (Fields 2005); (Kandel 2001)), it seems that traversing 17–142 shortest paths can be considered to correspond (i.e. when dividing the number of shortest paths by 3 or 4 to enable 3–4 repetitions) an aim to learn connectivity relying on the shortest paths for about *4–47 pairs of concepts* with every daily session of exploring hyperlink network of vocabulary. This result can be contrasted with and seems to resemble earlier estimates that a student can adopt daily about *4–9 new words* ((Lehr et al. 2004); (Kuhn & Stahl 1998); (Nation & Waring 1997)).

Instead of considering shortest paths of varying length we can make a simplifying assumption that language learning can be represented as a process of adoption of *direct relationships between nouns* belonging to a vocabulary and based on Table 12.3 for vocabulary A1&A2&B1&B2&C1&C2 this corresponds to adoption of 25153 unique Wikipedia hyperlinks connecting 2878 unique nouns in vocabulary. If we assume based on previously mentioned results ((European Commission 2012); (Cambridge English for Speakers of Other Languages (ESOL) / Cambridge English Language Assessment 2013)), that to reach the range of language ability levels A1–C2 requires about *1000–1200 guided hours* of learning, then for learning each of *25153 direct relationships* between *2878 concepts* there is on average *143–172 seconds* to be used. If we assume based on previously mentioned results a reading speed of about 200 words per minute ((Lewandowski et al. 2003); (Anderson 1999)) and an average sentence length of 20 words (DuBay 2004), during this given time range of 143–172 seconds it is possible to read about *477–572 words* corresponding to *24–29 sentences*. If this given time range is divided to for example *three spaced learning sessions* that offer exposure and retention then each of these three sessions has about *48–57 seconds* corresponding to about *8.0–9.5 sentences* devoted to learn one of 25153 relationships between 2878 concepts. Of course this kind of modelling about learning process is only a coarse simplification but we think that it can be useful to analyze learning also with this kind of simplifications to develop new methods to support learning.

To evaluate educational gains of exploration in hyperlink network of vocabulary we carried out an experiment to find out what kind of exploration paths emerge if we create a set of conceptual networks by identifying *the shortest paths* between *the highest-*

ranking start concepts and the highest-ranking end concepts in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 12.9. Thus we identified the shortest paths leading from 10 highest-ranking start concepts (including (occurrences in parenthesis): human (121), food (93), water (85), nature (79), entertainment (74), transport (72), nutrition (68), mind (66), infrastructure (65), globalization (63)) to 12 highest-ranking end concepts (including (occurrences in parenthesis): animal (108), human (106), water (106), earth (101), mammal (98), psychology (92), philosophy (90), law (86), religion (85), protein (85), science (80), carbon dioxide (80)) and since there is no need to find route from Human to Human and from Water to Water we gained altogether 628 *routes of shortest paths* between 118 pairs of concepts (our original aim was to take into analysis 10 highest-ranking end concepts like we took 10 highest-ranking start concepts covering 10 highest ranking positions of start concepts but we ended up taking two additional end concepts since we wanted to balance between taking 10 highest-ranking end concepts and covering 10 highest ranking position of end concepts). Among routes between 118 pairs of concepts 3 pairs of concepts had shortest paths containing three hyperlinks (on average 58.3 parallel paths between each pair of concepts), 78 pairs of concepts had shortest path containing two hyperlinks (on average 5.3 parallel paths between each pair of concepts) and 37 pairs of concepts had shortest paths containing one hyperlink (on average 1.0 parallel paths between each pair of concepts). All 628 routes contained together 1393 hyperlinks of which 736 were unique.

Table 12.10 shows among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts (hyperlinks occurring 5 or less times are shown in Appendix S due to space constraints).

Based on Table 12.10 Figure 12.3 illustrates among 1393 hyperlinks those *hyperlinks that occurred most often* in shortest paths between 118 pairs of concepts when considering only hyperlinks having at least 5 occurrences. Red color indicates 10 highest-ranking start concepts and 12 highest-ranking end concepts (together 20 concepts of which 2 concepts overlapping) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 12.9. Higher width of arrow indicates higher number of occurrences in range of 5–15 occurrences. In Figure 12.3 it appears that 18 concepts of 20 concepts become at least partially connected, only Protein and Psychology remain fully separated.

Table 12.10. Most occurring hyperlinks among 1393 hyperlinks in shortest paths between 118 pairs of concepts.

<i>Hyperlink</i>	<i>Occurrences</i>
mind->life	15
infrastructure->water; mind->evolution	14
energy->carbon dioxide	12
human->mammal; mind->biology; transport->human	11
mind->human	10
animal->carbon dioxide; globalization->carbon dioxide; human->earth; mind->matter; water->human	9
earth->carbon dioxide; food->human; globalization->earth; river->mammal	8
bacteria->carbon dioxide; earth->mammal; human->law; infrastructure->sustainability; mind->taste; water->earth	7
agriculture->carbon dioxide; ecology->carbon dioxide; entertainment->music; human->philosophy; human->religion; infrastructure->transport; mind->conscience; nature->human; nutrition->human; plant->carbon dioxide; water->life;	6
biology->earth; entertainment->writer; horse->mammal; infrastructure->museum; infrastructure->storm; life->animal; life->mammal; nature->science; nutrition->life; pollution->carbon dioxide; transport->carbon dioxide; transport->water; water->carbon dioxide;	5
(25 different hyperlinks, see Appendix S)	4
(61 different hyperlinks, see Appendix S)	3
(159 different hyperlinks, see Appendix S)	2
(444 different hyperlinks, see Appendix S)	1

Table 12.11. Among 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts, and among 736 unique hyperlinks of 1393 hyperlinks the most occurring start/end concepts, start concepts and end concepts. Number of occurrences shown in parenthesis.

Most occurring concepts among all 1393 hyperlinks			Most occurring concepts among 736 unique hyperlinks of 1393 hyperlinks		
<i>as start/end concept</i>	<i>as start concept</i>	<i>as end concept</i>	<i>as start/end concept</i>	<i>as start concept</i>	<i>as end concept</i>
carbon dioxide (162)	mind (135)	carbon dioxide (159)	carbon dioxide (54)	nature (46)	carbon dioxide (52)
human (142)	infrastructure; nature (83)	mammal (98)	water (53)	mind (39)	earth (40)
mind (138)	human (78)	earth (91)	nature (48)	food; nutrition (34)	water (39)
water (118)	globalization (63)	water (69)	human (44)	infrastructure (33)	mammal (36)
earth (107)	entertainment; food (62)	human (64)	earth (43)	entertainment (32)	animal (31)
mammal (100)	nutrition (59)	animal (54)	mind (40)	human (29)	protein (25)
nature (88)	transport (50)	protein (40)	mammal (37)	globalization (26)	law (23)
infrastructure (83)	water (49)	law; science (36)	food; globalization (35)	transport (20)	psychology (20)
globalization (75)	life (33)	life; philosophy (33)	animal; nutrition (34)	life (16)	science (19)
animal; life (66)	evolution (20)	religion (31)	infrastructure (33)	evolution (14)	philosophy (18)
food (63)	biology (18)	psychology (26)	entertainment (32)	water (14)	religion (16)
entertainment (62)	earth; energy (16)	evolution (20)	protein (25)	biology (10)	human (15)
transport (61)	sustainability (14)	biology (18)	science (24)	matter; sustainability; taste (7)	energy (12)
nutrition (59)	animal (12)	energy (16)	law; transport (23)	music (6)	globalization (9)
science (43)	matter; river (10)	sustainability (14)	psychology (22)	science; writer (5)	bacteria; river (7)
evolution; protein (40)	bacteria; fish (9)	globalization (12)	life (21)		biology; ecology; fish; plant (6)
biology; law; philosophy (36)	oxygen; plant (8)	transport (11)	philosophy (20)		agriculture (5)
religion (34)		matter; river (10)	evolution (18)		
		bacteria (9)			

12.4. Comparison of connectivity of concepts in hyperlink network and co-occurrences in language

We wanted to evaluate how well conceptual connectivity emerging between 20 concepts, consisting of 10 highest-ranking start concepts and 12 highest-ranking end concepts (2 concepts overlapping) in *Wikipedia hyperlinks* connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 12.9, correspond to the highest-ranking co-occurrence of these same *concept pairs in everyday language*. Appendix AC lists all 25153 unique hyperlinks between

3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns.

Conceptual relationships in all 628 routes of shortest paths between 118 pairs of concepts (for our observed set of 20 concepts) containing together *1393 hyperlinks* of which 736 were unique hyperlinks (shown in Appendix S) offered a suitable collection of relationships that we decided to compare to *n-grams* that are a collection of consecutive partially overlapping sequences of *n* words extracted from a text sample of corpus. Thus we retrieved a set of about *one million most frequent 5-grams* (in case sensitive form with part-of-speech tagging, downloaded in October 2013 from http://www.ngrams.info/download_coca.asp) that have been created based on *Corpus of Contemporary American English* (COCA) (N-grams data from COCA 2013) and we generated listings of the highest-ranking co-occurring nouns for each of our 20 concepts among all about one million most frequent 5-grams of COCA. We identified co-occurrences for both *singular and plural forms* of nouns and finally combined them so that our results which we report now contain both singular and plural forms even if our notation here uses only singular form of each noun. Table 12.12 shows the number of *co-occurring nouns for each of 20 concepts* among 5-grams of Corpus of Contemporary American English (number of all nouns that can contain more than one occurrence per each noun and number of only unique nouns). Comparing Table 12.12 with Table 12.11 shows quite much difference but for example concerning *five* highest-ranking concepts belonging to *all nouns of co-occurring nouns* and belonging to *start/end concepts among all hyperlinks* both tables share Water and Mind, and concerning five highest-ranking concepts belonging to *only unique nouns of co-occurring nouns* and belonging to *start/end concepts among only unique hyperlinks* both tables share Water and Nature.

Table 12.12 also enables to compare the *number of co-occurring nouns for 20 concepts* among one million most frequent 5-grams of COCA with *number of unique hyperlinks* (either departing hyperlinks in case of being a start concept or arriving hyperlinks in case of being end concept) in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 12.9). This comparison shows that even if distributions and ranking orderings of number of co-occurring nouns and number of hyperlinks have differences for this collection of 20 concepts it seems that average and median values of both co-occurring nouns and hyperlinks have relatively closely shared range. We think that this relatively closely shared range can indicate that coverage of *texts* corresponding to one million most occurring 5-grams have resemblance with coverage that can be reached with *exploration* of hyperlink network of vocabulary A1&A2&B1&B2&C1&C2. However, somewhat higher average and median values for the number of unique hyperlinks (in Table 12.9) than for the number of co-occurring nouns (in Table 12.2) seems to indicate that hyperlink network offers more dense and diverse connectivity than co-occurrence of words in 5-word-long sequences of text and we think that this finding supports suggested earlier mentioned claims that Wikipedia hyperlink network due to its scale-free small-world properties should indeed offer efficient and compact knowledge structure. Anyway it needs to be noted that these average and median values are computed based on concepts that have relatively high ranking in frequency lists of

everyday language and thus possibly have higher values than if computed based on larger and more diverse collection of words.

Table 12.12. The number of co-occurring nouns for each of observed set of 20 concepts among one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from COCA 2013) showing the number of all nouns that can contain more than one occurrence per each noun and the number of only unique nouns. For each of observed 20 concepts is also shown the number of unique departing hyperlinks as being a start concept and number of unique arriving hyperlinks as being end concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 and sum of these values (sum of number of unique departing hyperlinks as being start concept and number of unique arriving hyperlinks as being end concept).

<i>Concept</i>	Number of co-occurring nouns for current concept in about one million most frequent 5-grams of COCA (all nouns, i.e. can contain more than one occurrence per each noun)		<i>Concept</i>	Number of co-occurring nouns for current concept in about one million most frequent 5-grams of COCA (only unique nouns)	Number of unique departing hyperlinks as being a start concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 12.9)	Number of unique arriving hyperlinks as being end concept in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 12.9)	Sum of number of unique departing hyperlinks as being start concept and number of unique arriving hyperlinks as being end concept (a hyperlink becomes counted twice if occurring both as departing hyperlink as being start concept and arriving hyperlink as being end concept) in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (these values except those indicated with an asterisk (*) are shown also in Table 12.5)
law	1402		water	263	85	106	191
water	1099		law	254	28*	86	114*
food	632		nature	240	79	33*	112*
mind	561		food	171	93	65*	158
science	552		science	148	50*	80	130
nature	544		mind	128	66	34*	100*
religion	162		religion	62	29*	85	114*
psychology	153		earth	58	33*	101	134
animal	142		animal	51	19*	108	127
earth	114		psychology	40	42*	92	134
carbon dioxide	75		carbon dioxide	26	31*	80	111*
entertainment	64		human	24	121	106	227
human	41		entertainment	23	74	23*	97*
nutrition	39		philosophy	17	42*	90	132
philosophy	38		nutrition	16	68	18*	86*
protein	25		protein	14	14*	85	99*
globalization	17		globalization	11	63	32*	95*
mammal	3		infrastructure	2	65	24*	89*
infrastructure	2		mammal	2	39*	98	137
transport	0		transport	0	72	33*	105*
	average: 283.25			average: 77.5	average: 55.65	average: 68.95	average: 124.6
	median: 94.5			median: 33	median: 56.5	median: 82.5	median: 114

We think that *one million 5-grams* can coarsely correspond to *1000000 words* and with average sentence length below 20 words (DuBay 2004) 1000000 words corresponds to about *50000 sentences*. On the other hand we have, as mentioned earlier, identified that in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 there are *25153 unique hyperlinks* connecting 2878 unique nouns and each of these unique hyperlinks can be expected to have a relation statement (extracted from sentence surrounding hyperlink anchor in article text of start concept) which with average sentence length below 20 words (DuBay 2004) can coarsely correspond to about *503060 words*. Since according to Anderson et al. (Anderson et al. 1988) a student with average score in reading test reads 601000 words per year and with excellent score 4733000 words per year, we think that reading texts corresponding to one million 5-grams can be estimated to require *77–607 days* of school year and somewhat similarly reading texts corresponding to exploration of hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 can be estimated to require about *39–306 days* of school year.

Table 12.13 shows listings of five highest-ranking co-occurring nouns we have generated for each of 20 concepts among one million most frequent 5-grams of COCA (number of co-occurrences of noun mentioned in parenthesis), in case of shared ranking values we have listed all nouns included in five highest-ranking ranking positions.

When comparing *co-occurring nouns of 20 concepts* in Table 12.13 with *hyperlinks having at least 5 occurrences* in shortest paths between 118 pairs of concepts (as shown in Table 12.10 and Figure 12.3) there emerges only very limited overlap including *three pairs of concepts*: animal & life, carbon dioxide & water and human & nature. Therefore we suggest that comparing just the highest-ranking conceptual pairs of hyperlinks with the highest-ranking conceptual pairs of co-occurrences can offer relative limited possibility to identify shared conceptual pairs and thus comparison of conceptual pairs having also lower levels of ranking should be actively compared and paralleled to better identify shared conceptual pairs.

We continued our analysis with still same set of 20 concepts containing 10 highest-ranking start concepts and 12 highest-ranking end concepts (2 concepts overlapping) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 12.9. Now in contrast with Table 12.10 and Figure 12.3 relying on illustrating only hyperlinks having at least 5 occurrences we considered *hyperlinks having at least 1 occurrence*.

We generated Table 12.14 showing overlap that we identified between collection of *1393 hyperlinks* (of which 736 were unique hyperlinks) in the shortest paths between 118 pairs of concepts of our set of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (shown in Appendix S) and concept pairs generated so that each of 20 concepts is paired with all *co-occurring nouns* identified in one million most frequent 5-grams of COCA (N-grams data from COCA 2013). Those hyperlinks that have another hyperlink going into opposite direction in this same table are indicated with an asterisk (*). Five concepts of 20 concepts (Entertainment, Globalization, Infrastructure, Mammal and Transport) did not have any hyperlink of shortest paths to such a noun that would have co-occurred with these concepts among one million most frequent 5-grams of COCA.

Table 12.13. Listings of five highest-ranking co-occurring nouns generated for each of 20 concepts among one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from COCA 2013), number of co-occurrences of noun mentioned in parenthesis. In the case of shared ranking values all nouns included in five highest-ranking ranking positions are listed.

<i>animal</i>	<i>carbon dioxide</i>	<i>earth</i>	<i>entertainment</i>	<i>food</i>	<i>globalization</i>	<i>human</i>
plant (46)	emission (20)	heaven (12)	news (14)	processor (108)	economy (3)	relationship; resource (5)
species (11)	ton (10)	place (10)	show (10)	store (27)	age; force; impact; world (2)	animal; moon (3)
life (6)	level (9)	face; nation (6)	critic (5)	health (26)	business; context; era; face; process; result (1)	cost; material; nature; rest; role (2)
use (5)	atmosphere (6)	end (5)	industry (4)	water (25)		ability; ancestor; category; difference; environment; fact; foot; majority; place; right; size; species; study; subscale; way (1)
cell; variety (4)	concentration; water (5)	bond; country; people; person; sky (3)	form; world (3)	chain (24)		
<i>infrastructure</i>	<i>law</i>	<i>mammal</i>	<i>mind</i>	<i>nature</i>	<i>nutrition</i>	<i>philosophy</i>
country; destruction (1)	enforcement (118)	bird (2)	heart (57)	law; relationship (20)	professor (8)	professor (11)
	school (112)	species (1)	state (46)	thing (13)	director; food; science (5)	history (7)
	rule (94)		thing (39)	state (12)	department; epidemiology; research; sport (2)	science (3)
	professor (71)		doubt (35)	force; question (11)	activity; fiber; medicine; relationship; school; service; specialist; woman (1)	education; religion; university (2)
	firm (65)		question (28)	study; understanding (10)		degree; department; language; life; music; place; practice; qi; relationship; state; way (1)
<i>protein</i>	<i>psychology</i>	<i>religion</i>	<i>science</i>	<i>transport</i>	<i>water</i>	
source (7)	professor (50)	role (19)	professor (42)	no co-occurring nouns found	glass (68)	
pound (3)	school (15)	freedom (9)	technology (41)		pot (41)	
block; building; gram (2)	department (9)	professor (7)	art (30)		amount (40)	
amount; analysis; body; dna; electrophoresis; form; grain; surface; wheat (1)	course; sport (7)	life; politics; relationship; state (6)	math (21)		cup (30)	
	field (6)	establishment; exercise; study (5)	computer (18)		gallon (28)	

Table 12.14 part 1 of 2 (starts here and continues on next page). Overlap between collection of 1393 hyperlinks (of which 736 were unique hyperlinks) in shortest paths between 118 pairs of concepts of observed set of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 and concept pairs generated so that each of 20 concepts is paired with all co-occurring nouns identified in one million most frequent 5-grams of Corpus of Contemporary American English (COCA) (N-grams data from COCA 2013).

<i>Current concept (among all observed 20 concepts)</i>	<i>For current concept all co-occurring nouns in one million most frequent 5-grams of COCA that also exist in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (number of occurrences)</i>	<i>Hyperlink in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 that is between current concept and its co-occurring noun (number of occurrences), hyperlinks that have another hyperlink going into opposite direction are supplied with an asterisk (*)</i>
animal	species (11)	species->animal (1)
animal	life (6)	life->animal (5)
animal	habitat (1)	habitat->animal (1)
animal	nature (1)	nature->animal (4)
carbon dioxide	atmosphere (6)	atmosphere->carbon dioxide (3)
carbon dioxide	water (5)	carbon dioxide->water * (1); water->carbon dioxide * (5)
carbon dioxide	gas (2)	gas->carbon dioxide (2)
carbon dioxide	oxygen (2)	oxygen->carbon dioxide (4)
carbon dioxide	carbon (1)	carbon->carbon dioxide (2)
earth	life (1)	life->earth (3)
entertainment	no shared hyperlinks and co-occurrences	
food	nutrition (5)	nutrition->food (1)
food	salt (3)	food->salt (1)
food	sugar (2)	food->sugar (1)
food	butter (1)	food->butter (1)
food	energy (1)	food->energy (2)
food	soup (1)	food->soup (1)
globalization	no shared hyperlinks and co-occurrences	
human	nature (2)	nature->human (6)
human	species (1)	human->species (1)
infrastructure	no shared hyperlinks and co-occurrences	
law	institution (5)	institution->law (1)
law	tax (4)	tax->law (2)
law	college (3)	college->law (1)
law	crime (2)	crime->law (1)
law	spirit (2)	spirit->law (1)
law	democracy (1)	democracy->law (1)
mammal	no shared hyperlinks and co-occurrences	
mind	body (19)	mind->body (2)
mind	life (6)	mind->life (15)
mind	nature (3)	nature->mind (3)
mind	spirit (2)	mind->spirit (2)
mind	evolution (1)	mind->evolution (14)
mind	idea (1)	mind->idea (1)
mind	matter (1)	mind->matter (9)
nature	life (6)	nature->life (3)
nature	science (6)	nature->science (5)
nature	mind (3)	nature->mind (3)
nature	art (2)	nature->art (1)
nature	human (2)	nature->human (6)
nature	matter (2)	nature->matter (1)
nature	animal (1)	nature->animal (4)
nature	consciousness (1)	nature->consciousness (2)
nature	evolution (1)	nature->evolution (2)
nature	phenomenon (1)	nature->phenomenon (1)

Table 12.14 part 2 of 2 (started on previous page and continues here).

<i>Current concept (among all observed 20 concepts)</i>	<i>For current concept all co-occurring nouns in one million most frequent 5-grams of COCA that also exist in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 (number of occurrences)</i>	<i>Hyperlink in shortest paths between 118 pairs of concepts of 20 concepts in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 that is between current concept and its co-occurring noun (number of occurrences), hyperlinks that have another hyperlink going into opposite direction are supplied with an asterisk (*)</i>
nutrition	food (5)	nutrition->food (1)
nutrition	science (5)	nutrition->science (3)
philosophy	science (3)	science->philosophy (2)
philosophy	education (2)	education->philosophy (2)
philosophy	life (1)	life->philosophy (3)
protein	dna (1)	dna->protein (1)
psychology	education (2)	education->psychology (2)
psychology	science (1)	science->psychology (1)
religion	life (6)	life->religion (3)
religion	science (3)	religion->science * (1); science->religion * (2)
religion	society (1)	society->religion (1)
religion	university (1)	university->religion (1)
science	technology (41)	technology->science (2)
science	university (8)	university->science (1)
science	education (7)	education->science (2)
science	nature (6)	nature->science (5)
science	nutrition (5)	nutrition->science (3)
science	philosophy (3)	science->philosophy (2)
science	religion (3)	science->religion * (2); religion->science * (1)
science	knowledge (1)	knowledge->science (1)
science	psychology (1)	science->psychology (1)
transport	no co-occurring nouns for concept "transport"	
water	ice (26)	ice->water (1)
water	blood (6)	blood->water (1)
water	fish (5)	water->fish (3)
water	river (5)	water->river * (2); river->water * (2)
water	ocean (4)	ocean->water (1)
water	salt (4)	salt->water (1)
water	sugar (4)	sugar->water (1)
water	oxygen (2)	oxygen->water (1)
water	desert (1)	water->desert (2)
water	plant (1)	plant->water (2)

Now based on results of Table 12.14 it appears that a promising amount of overlap emerges between hyperlinks in *the shortest paths* between 118 pairs of concepts and *co-occurring nouns* of 20 concepts. We think that this relatively high level of overlap gives convincing support to suggest that a student's explorations in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 can be considered to offer such *natural connectivity* of concepts that resembles connectivity existing in large corpus of natural language. Anyway, it is interesting to note some differences in emphasis so that among shared hyperlinks and co-occurrences the highest-ranking hyperlinks include mind → life (15 occurrences), mind → evolution (14 occurrences) and mind → matter (9 occurrences), whereas the highest-ranking co-occurring nouns include conceptual pairs technology ∝ science (41 occurrences), ice ∝ water (26 occurrences) and mind ∝ body (19 occurrences).

Based on Table 12.14 we generated Figure 12.4 illustrating overlap that we identified between collection of 1393 hyperlinks (of which 736 were unique hyperlinks) in the shortest paths between 118 pairs of concepts of our set of 20 concepts in

Chapter 13. Concluding remarks

We have proposed new computational methods and frameworks to support personalized learning with collectively created educational resources and to explore human-built knowledge structures for various tailored pedagogic purposes. We hope that the proposed methods can be pointing direction towards fertile inspiring new ways to foster learning and aid challenged learners.²⁵ It is also evident that some innovations can help greater population groups than some others but on the other hand smaller population groups can sometimes have much greater need for the innovation (for example persons belonging to minorities that have a specific special need). For example among people with special needs, such as impaired people, new innovations can open totally new ways to express oneself and thus innovations directed to them can revolutionize everyday life much more than some other innovations directed to ordinary people and providing just minor change in living habits. In fact we think that when developing educational technology, the people with special needs should be among primary targeted user groups since they appear to benefit most from even relatively simple innovations and they have strong need for new solutions enhancing independent management of life.

13.1. Supporting intuitive and flexible forms of learning

In our research we have identified a strong need to enable learners to *create and explore knowledge* in relatively unconstrained and easily expandable form. Also it seems that enabling supporting compact ways to illustrate knowledge is important. There are many ways to approach same single piece of knowledge and position it in a wider entity. It seems that in traditional school environment the local community and culture typically give some motivation for having *shared and complementing perspectives* among learners and their teacher during learning sessions. For example the geographical location and the country's history can give strong influence on how surrounding world is typically perceived and understood. The cultural background can easily influence education about learning topics concerning social and humanistic issues but also learning topics related to natural science like mathematics and physics, since teaching needs concrete examples that typically use such objects found in the current cultural environment (for example indicating how urban or rural the environment is and what kind of climate is dominating).

²⁵ Especially in engineering and technology related fields of research we are inherently dealing with constantly evolving process of computer systems, user interfaces, sensors etc. and thus many new ideas and solutions will quickly become obsolete and old-fashioned. Only much later in historical perspective it can be more clearly evaluated what initiatives have had a positive long-lasting effect for the development.

We have developed and evaluated experimentally computational methods dealing with recommendation of *fruitful learning paths*, networks of paths and even greater entities. We think that a related area that deserves attention in further research is *prediction of the learner's initiatives*. It seems for us that current state of research about computer-supported learning and also our work has strongly focused on suggesting promising resources based on the current position and path in the knowledge network but there is a need to extend analysis to what is predictable based on the learner's prior activities and the patterns observed in activities of sufficiently statistically reliably large population samples. One important issue is also to develop methods to make *synthesis about the learner's progress* in learning so far and how overlapping entities of knowledge and overlapping (possibly conflicting) perspectives can be taken into account.

We think that many interesting *cultural perspectives* could be addressed by methods similar to the methods we proposed by extending analysis to various *language versions* of the Wikipedia and their similarities and differences. However, it needs to be cautious in comparison since it is hard to identify if some language versions have been generated independently from the main language versions or not (since there is often a temptation to copy from the most covering extensive article to other translations) and if they are written by someone really who has grown up in the typical culture of that language. Furthermore for example Spanish and French are used in a diversity of large populations in cultural locations around the world thus making generalizations hard. If privacy issues can be sufficiently addressed, perhaps *tracking the geographical region* for each edit and retrieval of an article could offer help to distinguish specific cultural patterns of Wikipedia content that can then support learning with diverse cultural perspectives.

Educational solutions relying on the Wikipedia, or other wiki based encyclopedias, face challenges that include *vandalism* and contributions that intentionally or unintentionally introduce unrelated, false, commercially promoting or copy-righted material. We think that popular articles and articles dealing with complex and sensitive issues may give a specific interest for people seeking attention to make provocative and vandalous edits. Thus when managing education of children and there is strong need to support learning correct facts right from the start there is can be a unpleasant risk of being misconducted and offended by manipulated content in the Wikipedia. Thus even when exploring very basic vocabulary there is a risk to be exposed to unsuitable material and only one single false edit is enough to cause this. Articles receiving a lot of vandalous edits get very high edit counts that can misleadingly give an impression that these articles have been ambitiously developed thus biasing usefulness of edit count as an indicator of article quality.

It is also educationally challenging that actually many of the most fundamental and popular topics concerning life and world often have so much *conflicting schools of thought* and sensitive or controversial themes that the freely edited encyclopedic articles can suffer from heavy edit wars thus weakening the opportunities to get an objective viewpoint for learning. These topics include for example sex, religion, human races, wars, ethnic conflicts, territorial disputes, evolution theory, animal rights, imperialism

and colonization. So even though it is especially important for students to learn about these fundamental topics and gain critical objective and analytical understanding of them to promote civilized and peaceful living, the freely editable learning content remains vulnerable for bias and provoking unnecessary prejudice and conflicts. There remains a need to develop methods to track and indicate to learners and educators those articles that seem to contain highly misleading and excessively subjective coverage about complex controversial topics.

Afterwards when evaluating our research reported in consecutive publications [P1]-[P8] there seems to emerge a trend of *progressively changing focus*. We think that while in the first publications we give relatively much emphasis on developing practical technology enabling students to use concept maps to synthesize collaborative work and to represent a student's exploration in hyperlink network of the Wikipedia, then in later publications we represent methodology that is not necessarily so much relying on using concept maps per se or visualizing learning process but instead seems to emphasize developing general modeling of human thinking and language structure on relatively abstract level. We hope that this changing focus can possibly offer additional perspectives to many challenging characteristics concerning developing computational methods that aim to represent educational material with conceptual networks and to offer suitable kind of guidance and inspiration for a student to adopt new knowledge.

One general challenge is that basic *concept maps* that we have decided to use to represent knowledge structures do not enable easy ways to visualize some *relational aspects of knowledge*. For example links depicting relations can become messy especially if they are intended to be only linear, and if they are allowed to be curvy they require cumbersome following of the line. Thus using concept maps seems to require making hard decisions between alternative layouts of concepts and prioritization which concepts get more optimally visualized links depicting relations. With weakly motivated layout decisions some concepts may get prioritization without actually deserving it. Also links denoting that some concepts belong to greater entity (or to even nested hierarchies) are difficult to visualize especially if several concepts belong to several different entities. We think that there is a need for research to better understand how conceptual relations can be fruitfully indicated in concept maps with for example colour coding, dotting, font size, font effects, various shapes of bubbles/squares and even animation.

In contrast with many previous proposals in the fields of computer science and education, in our research we have not only developed new methods for knowledge management but also implemented *functional prototypes* that can be used in various educational contexts for many pedagogical purposes. In addition we have carried out various *empirical experiments* in real education setting to test our self designed and implemented software prototypes and to model characteristics of learning with conceptual networks. We do not know any previous research that has created similar results as our work especially concerning educational use of such cumulative and explorable knowledge structures that we have generated based on Wikipedia online encyclopedia.

We think that the Wikipedia can offer useful ways to model *human thinking* and language structures that can be exploited in knowledge adoption with cumulatively growing vocabularies and cumulatively growing conceptual networks relying on hyperlink network between concepts of the vocabulary. However to be applicable for representing and supporting vocabulary adoption of a growing child one challenge is for example that the hyperlink network of the Wikipedia that is used to connect concepts of vocabulary is actually largely created to represent an *adult perspective* in both selection of concepts that have been included into the encyclopedia (i.e. supported article topics, writing style and formatting of articles) and selections made when hyperlink network has been built (i.e. what words in the article text deserve to become hyperlink anchors and thus hyperlinked by Wikipedia editors) .

13.2. Some prospects concerning proposed methods

In publications [P1]-[P8] we have proposed various methods. These methods aim to support collaborative learning and guided exploration in hyperlink network of the Wikipedia as well as building concept map structures. These methods also aim to support adoption of vocabulary and new knowledge following principles of spaced learning and relying on efficient scale-free small-world networks and exploiting collaboratively edited knowledge of Wikipedia online encyclopedia. In the following we try to briefly conclude some features we consider essential for these proposed methods and mention some aspects that we think could be considered in future work.

In publication [P1] we proposed a new educational framework (that we referred to as a collaborative learning platform) to assist *learning conceptual structures* in a *collaborative environment* both online and offline, and we have implemented a prototype enabling collaborative ideation to build shared concept maps representing conceptualization of learners. To support exploitation of the specific complementing strengths of each collaborator we proposed that a educational framework (a collaborative learning platform) monitors activity patterns of each collaborator role based on Competing Values Framework and if they differ sufficiently from the expected activity profiles the system asks the representatives of this role to adjust that activity to follow the expected profile.

In the future, the guidance could be extended to cover various aspects of ideation. The system could offer personal advice *how to communicate* most productively in the current context. This could deal with group cohesion, timing, goal-orientation and distribution of tasks. Guidance could also help to elaborate other's ideas and to give feedback about them. The system could tell if immediate or postponed criticism would be needed to maintain fertile ideation process.

In the proposed method guidance for collaboration generated by the educational framework (collaborative learning platform) is based solely on the *activity patterns of collaboration* and thus collaborators are expected to be responsible about the factual content of shared knowledge. We think that this design decision fruitfully enables to avoid computational complexity and on the other hand enables to have knowledge

management process to be carried out by the collaborators in natural form. Thus we do not expect the system to be necessarily able to evaluate ideas itself using text analysis although it would be useful and advanced computational models should be developed for that purpose as well. Furthermore, *forming synthesis* and finding mutual agreement of ideas could be assisted by proposals initiated by the system when certain collaboration patterns indicate that time is right for that. Naturally the proposed collaborative method can be supplied with external knowledge structures like generating concept maps based on hyperlink network of the Wikipedia as we proposed in publication [P2].

Present theories concerning the principles dictating the personality and collaboration are still ambiguous and thus it can be advisable not to get too fixated on any single theory that tries to explain processes of learning and collaboration. For example *neuroscience* accompanied with *computational simulations* can possibly relatively soon verify some theories of human thinking and to disqualify some others. Thus, for time being it might be important to focus research efforts on general techniques that could hopefully be applicable what ever specific theories prove to be valid in the long run. A breakthrough in collaboration theories might also come from finding new kind of *transformations or mappings* between individual patterns of ideation. Besides ideation, collaboration practices need to be explored on even wider scale. For example, domains of creative problem solving, problem-based learning and decision making can offer useful application areas for new innovative collaborative methods and educational frameworks.

In publication [P2] we proposed a new method for *guided generation of concept maps* from open access online knowledge available in *Wikipedia online encyclopedia*. The method extracts semantic relations from sentences surrounding hyperlinks in the Wikipedia's articles and lets a learner to create customized learning objects in real-time based on collaborative recommendations considering her earlier knowledge. Wikipedia articles and interconnecting hyperlinks define conceptual relationships which can be explored by the learner thus forming learning paths and building concept maps representing his conceptualization.

In the proposed method learning efforts become well documented and the produced *visualizations* can be easily reused, updated and shared. By tracking the building process of concept maps, teachers can practically evaluate learning progress in respect to learner's individual resources. The method also enables teachers to update their own knowledge and plan curriculum.

By analysing the temporal construction phases of a concept map can assist identifying and responding to various *learning styles*. With small modifications the method could be transformed to generate automatically concept maps for school lessons with a great variation and always up-to-date. These concept maps could be tailored to address varying topics and learning styles of each attending learner. Extending the method to *parallel language versions* of the Wikipedia or other wikis could enable new ways to understand cultural and language related differences in conception and ontologies. In addition, learning foreign languages could be supported with comparison

of conceptual relations simultaneously in two language versions. Furthermore, in *special education* and assistive tools various everyday processes could be illustrated.

The method can supply information retrieval and question answering with close personalized touch. A great diversity of easily digestible pieces of knowledge can be provided to the learner with the method. Even if the learner is challenged in her cognitive skills, the method still guarantees her rights to make the ultimate decisions about the learning path to proceed.

Besides text, the concept maps could be easily transformed to exploit *multimedia content*. In addition, various metrics could be applied to assist the learner to identify the most mature and trusted content in the online knowledge resource. Thus the method could promote using the most extensive and reliable learning paths. In this respect some possible methods to generate alternative exploration paths are proposed in publications [P3] and [P4] to exploit article statistics and topology and evolution of hyperlinks.

Even if the method occasionally provides inaccurate knowledge it can be exploited as a learning resource that urges the learner to critically evaluate the content and make rephrasing that is well mapped to her previous conception. Incomplete explanation phrases offered to support building concept maps can be considered as a valuable way *to activate the learner* to excel oneself in personal knowledge acquisition and formulation. Completing the phrases can be used as a personalized exercise to evaluate learning progress so far. The learner becomes actively encouraged to rephrase the relations suggested by the method so that they fully correspond to her own intuition. In contrast with many other research proposals in this field, we have implemented a fully functional prototype and with experiments verified the success of our proposed method.

We think that too often educational practices rely on unverified beliefs. We want to actively promote bringing theoretical research results into everyday school environment to increase productivity and quality of life. Due to *modular structure*, the functionality of our method can be flexibly extended and modified later to exploit new better modules following the latest pedagogical insight. We also think that the patterns of learning emerging in school life should be exploited much more to develop new theoretical models. The proposed method and the related prototype indicate new possibilities to facilitate *tracking learning events* at schools to find better models to support learning. Long-term studies with large populations are needed to better understand the long-lasting and slowly evolving learning processes in individual minds. It is possible that earlier research has too optimistically aimed at single models that could favourably support different learners. We think that the proposed method can give directions for new *learning practices that evolve* and mature together with each individual learner. For example, curriculum and learning objects may often be too fixed and aimed at an average learner only. To liberate education from too homogenous one-for-all standards we need to cope with challenges of identifying the great variety in the learning progresses of individuals. To really address all learning difficulties it is a necessity to take into account different personalities, temperaments and interaction styles acquired during the early childhood. Increasing personal knowledge and educational level should be seen as an important goal for everyone, affecting only positively to well-being.

We think that the proposed method offers practices to be considered as mediators to enhance understanding individual *learning styles* and how they are related to *educational needs*. To capture the essence of the holistic learning process performed by an individual mind requires new analytical approach that should increasingly exploit latest technology, such as information networks, mobile communication and virtual teams. In school, the educational practices should aim to provide *life-long learning skills* not only based on today's requirements but also trying to predict tomorrow's requirements. To stay in the first wave, it is important to model how new knowledge can be submerged with prior knowledge and how rich *adaptive representations* can support this process. One possible way to address these needs is proposed in publication [P6] that presents an educational concept mapping method based on high-frequency words and Wikipedia linkage.

We think that learner-driven *unconstrained experimenting* with various conceptual structures can be a key factor in the development of new advanced support tools. It seems to us that extensive indexing of knowledge from online resources before a learning process has even started cannot fully satisfy the individual needs of a learner. We think that the learner should get thoughtful guidance but eventually to be free to make creative initiatives following her intuition. We think that exploration patterns should be well documented so that they could be directly exploited in building *collective knowledge structures*, beneficial for other learners later as well. One possible way to address these needs is proposed in publication [P5] that presents a collaborative framework for agglomerating pedagogical knowledge with concept maps. Along the years, learning process of an individual should produce conceptual structures that illustrate her *core understanding*, like an autobiography in a form of a visualized relational database.

We aim to develop further the pedagogical advantages of our proposed method. The method can be extended to retrieve automatically concept maps about a wide range of topics to provide *ready-made learning objects*. These concept maps could be used as an augmented user interface for browsing the Wikipedia. Even in offline mode the concept maps could serve as a *compact search tool* representing conceptual relations since many fundamental facts are fixed and do not change daily. With a shared educational framework (collaborative learning platform) individuals could use the methodology both online and offline to build *mutually agreed concept maps*. This should support constructive dialogue to find resolution ensuring that all opinions become heard.

We think that it is important that our method supports drawing concept maps even without retrieving knowledge from the Wikipedia. In the case that the Wikipedia is temporarily inaccessible or it provides irrelevant or false information it is important that the user can freely decide the structure and labelling of the concept map. We think that the proposed method shows how important it is to support free exploration in conceptual spaces and recognize many equally valid *alternative conceptions*. We think that learning through trial and error can well support iteratively refining processes of human thinking.

Future research should give attention to modelling how the construction of pedagogically favourable concept maps really relies on the features of *unrestricted*

exploration. Thus there is a need to explain how the learner actually can benefit from experimenting with the keywords of a learning topic in a concept map following her intuition. Recommendable practices of knowledge management should be identified and used for developing new adaptive tools that support learning, innovation and creative problem solving. Domain-independent methods to explore knowledge and represent it illustratively should have a high priority in the research agenda.

In publication [P3] we proposed a new semi-automated method for generating *personalized learning paths* from the Wikipedia online encyclopedia by following *inter-article hyperlink chains* based on various rankings that are retrieved from the *statistics of the articles*. Alternative perspectives for learning topics are achieved based on hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate, editing rate, or user-defined weighted mixture of them all enabling the learner to build independently concept maps following her needs and consideration.

In publication [P4] we proposed a new method to support educational exploration in the hyperlink network of the Wikipedia online encyclopedia and extending the method introduced in publication P3. Method of publication of [P4] extends method of publication [P3] in respect to three important new features: the learner can simultaneously operate with *parallel ranking lists* of hyperlinks, the concept map construction emphasizes building diversely *branching structures*, and different consecutive *temporal versions* of Wikipedia articles can be browsed.

Since methods of publication [P3] and [P4] are closely related in the following we try to discuss about them together and thus we try to conclude some features and future prospects we consider central for such a method that supports generation of personalized learning paths based on Wikipedia article statistics as well as topology and evolution of hyperlinks in the Wikipedia.

We have evaluated *ranking hyperlinks* of the article in respect to five different features based on article statistics and we think that these features can be considered to correspond to a set of fruitfully complementing different characteristics of knowledge structures of the Wikipedia. In our experiments we found distinctive ways to differentiate exploration of hyperlinks based on the features preferred by the learner. Using various rankings it is thus possible to provide *alternative perspectives* to knowledge and thus enable the learners to build independently favourable learning paths following their personal needs at the moment.

Concepts belonging to various domains of life and to various abstraction levels in a certain topic have obviously different tendencies to support the proposed five statistical features. Also, features can have many *hidden correlations* that should be taken into account for a balanced use of statistics. High editing rate typically produces high article size. Typically each single event of editing article increases also viewing rate if the editor wants to check the finished version of article after editing. When building learning paths, our proposed method possibly too optimistically expects high relation between all consecutive concepts in a *traversed chain of hyperlinks*. Hyperlinks of an article can point to target articles that deal with topics that are opposite or ambiguous to the title of current article. Unfortunately, it is hard to develop general methods that could reliably identify the exact type of relation between target article and current

article. Extracting relation statements from the sentence surrounding the hyperlink can also be troublesome since often the sentence does not explicitly define the relationship between the title of current article and the title of target article, but instead describe something else.

When building learning paths, a major challenge for semantic continuity is that some measures based on the *characteristics of target article* may not indicate well the *actual relatedness* between current article and target article. For example, if ranking of hyperlinks is based on viewing rate, the target article having the highest viewing rate is prioritized. But this viewing rate consists of a great variety of visits arriving to the target article through various hyperlinks, not only from current article. Thus, viewing rates describe just the overall distribution of visits to individual Wikipedia articles and fail to tell how the preference to visit a certain target article varies depending on the current article.

The method could also somehow take advantage of the fact that typically many changes in an article are performed in bursts, for example after related news has been published in the media. Various *navigational aids* have been introduced to the layout of Wikipedia articles, for example category tags and “See also” section as well as so called navboxes and infoboxes. Also redirects, disambiguation pages and “What links here” queries assist finding related articles. However, we argue that these assistive functions complementing each other cannot clearly recommend the most promising hyperlinks for further exploration. To increase efficiency of exploration and to ensure finding the most relevant hyperlinks, there is a need for intuitive visualization of *adaptive ranking* of hyperlinks of the current article.

There are limitations with the current method especially since it was purposefully designed to be simple and *computationally easy*. The statistical features used with the method could be chosen in various alternative ways. If the online services we suggested to be used for querying statistics should become shut down it still remains possible to retrieve *statistics with alternative implementations*.

Since a lot of articles of the Wikipedia present facts that have a low probability to become constantly updated or seriously questioned, we think that our method could be successfully used also *offline*. Despite of its huge coverage, the plain textual content of English language version of Wikipedia can be stored locally in *one compressed file* that can be estimated to require storage space about ten gigabytes as of June 2013. The method might use also the article statistics from just off-line sources. We suggest that already the current knowledge structures of the Wikipedia and statistics available so far can enable creating relatively reliable ranking of hyperlinks that reflects *conception of global community*. Relying on off-line content would enable using the method with very low computational costs and minimal delay.

Traversing just a short chain of hyperlinks in the Wikipedia can enable to encounter essential educational knowledge about a desired topic, but it is hard to define requirements for an *optimal exploration path*. Generation of recommendable exploration paths to the learner should be favorably personalized in diverse contexts and reached with a limited computational load. It seems that desired *educational perspectives* can be efficiently offered to the learner by chaining ranked hyperlinks that

have correlation between a *simple statistical feature* of both current article and target article.

It is possible to explore just the relations between the *latest versions of articles*. On the other hand, browsing *consecutive temporal versions* of an article offers alternative insight by showing emergence of knowledge clusters. Using these two parallel approaches should enable the learner to gain complementing ways to process and adopt knowledge. To let the learner *emphasize earlier knowledge or definitions* in her browsing experience, we have suggested that the generation of recommended exploration paths can favor hyperlinks having previously encountered target articles or hyperlinks belonging to the introduction section of current article.

The proposed method and experiment have indicated a promising unexplored area for research concerning new methodology to adaptively explore the knowledge space of the Wikipedia. We suggest that the method we have developed for the Wikipedia can be relatively well applied to also other *collaborative knowledge management environments* and even intellectual mental processes in human mind.

In the future research there is a strong need for further classifying various features that can be used in ranking of hyperlinks that connect concepts (or articles). It can be possible to identify individual most favourable *features for each domain* of knowledge. These specific features could enable exploring knowledge in most coherent manner taking into account special characteristics that are typical for this domain. It is also important to develop methods that can address individual *characteristics of every learner*. For each learner it could be identified what are the features that need to be used in ranking of hyperlinks to fulfil his special personal needs. For example, preferred learning style, personality and hobbies of the learner could be considered when setting the ranking criteria that affect which hyperlinks become promoted to the learner. Furthermore, it would be advantageous that the learner could himself make adaptively consistent decisions about what features to prioritize in ranking when exploring varying learning contexts. In many cases, *user-defined ranking criteria* should not probably support just one perspective but instead to be a dynamic weighted mixture of them all.

In addition, it is important to develop advanced but still computationally sustainable analysis methods that help to rank alternative hyperlinks and thus to find most promising learning paths. It is important to have such analysis methods that are not dependent on any proprietary online service. To effectively develop and ensure automated knowledge management it is important to support *open access knowledge bases* and *open source modules*. Interfaces should be kept as interoperable and standardized as possible to best promote updating individual components of modular applications or replacing them with alternatives. Knowledge management tools should be actively introduced for using them in *ordinary everyday life* for example in education, problem solving, decision making, design and innovation. Research should emphasize access for all since knowledge tools are often most crucial for people with special needs. The efforts should aim at providing a better quality of life and letting the learner to excel oneself and follow his personal interests.

In publication [P5] we proposed a new educational framework, *ConceptMapWiki*, that is a wiki representing pedagogical knowledge with a *collection of concept maps*

which is collaboratively created, edited and browsed. The learners and educators provide complementing contribution to *evolving shared knowledge structures* stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria. Pedagogically motivated learning paths can be collaboratively defined and evaluated, and educational games can be incorporated based on browsing and editing concept maps.

We think that knowledge structures and user logs gathered with the method can be exploited in daily educational work for *evaluating learning progress* of students, modeling collaborative learning processes and identifying patterns of successful learning. The method could be easily augmented with such educationally useful components that resemble those that have been developed for traditional wikis, data mining and clustering algorithms.

The method could automatically suggest which concept maps most urgently need refinement and recommend *promising learning paths* based on concept maps having popular browsing patterns and active edit histories. Simple tentative concept maps and supplementing hyperlinks could be automatically generated based on *hyperlink network of the Wikipedia*. In addition, the method might help in curriculum planning and developing semantic analysis and building ontology models. There is a need for comparative research to evaluate benefits of alternative wiki technologies and ontology models and to synthesize their methodologies to develop general theory for creative problem solving and pedagogical guidance in computer-assisted learning.

In publication [P6] we proposed a new computational method to support the learner's *knowledge adoption* based on concept mapping relying on *three perspectives*: learner's knowledge, learning context and learning objective. Each perspective is represented by a learning concept network that is generated based on a set of *high-frequency words* from a representative text sample that are connected based on the *shortest hyperlink chains* between corresponding *Wikipedia articles*. The learner explores ranking-based routings connecting learning concept networks by expanding a concept map.

To keep our method computationally and pedagogically fluent and transparent, we used relatively simple criteria to form a *learning concept network* by connecting high-frequency concepts in text samples based on the shortest hyperlink chains between corresponding Wikipedia articles. As an alternative and supplementing the Wikipedia linkage the shortest paths can be retrieved from a collection of *concept maps drawn by learners*. The proposed method is independent from any service provider since collections of vocabularies, conceptual relationships and shortest paths in conceptual networks can be generated with *various alternative resources*. Besides retrieving learning objectives from Wikipedia articles, the method can be also applied to explore directly concept maps drawn by teacher and learners, to support reaching complementing consensus.

The current model based on learner's knowledge, learning context and learning objective could be augmented with components addressing for example types of personality, community and education. *Concept ranking* and *hyperlink ranking* schemes could take into account desired semantic relatedness measures and maturing of the

Wikipedia. High-frequency concept lists and rules of conceptual chaining could be modified according to personal needs. To assure pedagogic gain, quality of text samples used to generate learning concept networks and exploration patterns of students could be socially annotated. Besides nouns, other conceptual classes could increase the pedagogic and expressive value of the method.

Since *small-world networks* seem to bind brain functions and the Wikipedia (and also *scale-free properties* identified in the Wikipedia possibly have correspondence in brain functions), we suggest developing related models for educational tools. Besides the Wikipedia, we expect our method to be applicable to other small-world networks, such as wikis, the World Wide Web or even real-life social networks at schools. The learner could have different learning context networks defined for different *school activities, collaborator roles, educational levels* and so on. By comparing how different learners rely on contextual recommendations one could identify common *learning challenges* and match collaborators best complementing each other. Extensive further research and experiments in real educational setting are needed to augment models and make pedagogically verified support tools. Since literacy is a crucial for self-sustained development for all children, we hope that future research can develop powerful sequential models for guiding the learner's exploration with any context and objective to balanced adoption of new knowledge.

In publication [P7] we proposed a new educational framework relying on *pedagogic conceptual network* generated by linking the most essential concepts of learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary. To *adopt vocabulary* the learner traverses links of pedagogic conceptual network along learning path generated by method in sequential process having tailored variation and repetition computed based on theory of *spaced learning*. The learning path is shown to learner as a sequence of compact relation statements extracted from sentences surrounding hyperlinks in Wikipedia articles, supplied with set of visualizations based on main verb identified in them.

In the proposed framework exploration in hyperlink network is affected by various *adjustable parameters*. Based on learner's needs and teacher's advice or earlier testing, learner manually sets nine parameters including session vocabulary size, degree of new content, session duration, learning speed, degree of required adoption, degree of exposure repetition, degree of retention repetition, interval of exposures and interval of retentions. When starting new learning session method first evaluates learner's initial *conceptualization level* based on recall about shown sample of concepts how they are linked, and the method supplies each concept of pedagogic conceptual network with a value representing measure of adoption.

For each concept, the framework keeps a record and *updates five values*. Besides measure of adoption, they include measure of exposure repetitions (number of spaced exposures of the concept so far), measure of retention repetitions (number of spaced retentions of the concept so far), time between exposures (average time between spaced exposures of the concept so far) and time between retentions (average time between spaced retentions of the concept so far). At each step of proceeding to next concept along learning path, all five values of that concept are updated.

When generating learning path, the framework primarily guides learner to traverse in pedagogic conceptual network at each step from current concept next to a concept having now the *lowest measure of adoption*, along the *shortest connecting hyperlink chain*. As a part of the research we experimentally generated a variety of pedagogic conceptual networks for selected learning topic vocabularies encountered often in educational setting addressing diverse combination of characteristics of a learner.

Future work should heavily invest in rapid agile prototyping with diverse populations of learners in versatile real educational settings to gather large quantities of behavioral data for fine-tuned modeling of intuitive *personalized learning practices* when learners adopt vocabulary and new knowledge. With increasing penetration of smart phones and tablets through whole society we are living a critical period when the educational market becomes shared with long-lasting dominance by most innovative solutions and public education faces risks to become locked-in to proprietary commercial platforms. So academic community should be now actively involved in coordinating and defining standards that ensure support for *sustainable development* of educational tools and keep open access and open content on high level of research agenda. Like in our suggested framework, new systems should inherently have flexible functionality supporting various kinds of educational needs and context, letting learner explore and express her creativity and personal identity.

There is a need to develop easily *tailorable user interfaces*, plug-ins and input devices so that the learners themselves can adjust and select most motivating ways to process knowledge in various forms to be incorporated to learning activities and addressing their background. Adaptive visualization and exploration of knowledge structures should exploit pioneering technology for personalization, for example promising generic input solutions addressing eye/gesture tracking, touch response, EEG bio-feedback, geo-positioning, inertia sensing and image recognition aspects. New tools should promote easy ways for the learners to share and collaboratively cumulatively *contribute to knowledge building process* in learning communities with captivating and inspiring experiences.

When learners intuitively invent, form and adopt new *educational practices* about how to link, agglomerate and traverse pieces of knowledge in their minds there needs to be ways to conveniently document and define these processes for future use and refinement. Like in our framework, new systems should offer recommendations for exploration in educational content on *various levels of abstraction* with such representation schemes that flexibly support chaining and looping in branching conceptual networks and capturing these exploration patterns into *expressive reusable templates*. Rich collection of automatically generated and updated templates should be instantly available for typical learning settings but they could be also modified and refined iteratively to address individual personal preference or collaboratively edited and ranked to form mutually agreed standards.

In publication [P8] we proposed a new educational framework relying on *cumulative conceptual networks* based on *hyperlink network of the Wikipedia* connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the *distribution of enabled hyperlinks*

connecting concepts belonging to current vocabulary. Adoption of knowledge can be gained by exploring hyperlink network and *the shortest paths* between concepts of vocabulary (especially concepts having highest rankings and strongly rising rankings). Publication [P8] also estimates properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to *six language ability levels*.

We think that already at the moment the Wikipedia basically contains so much useful knowledge that it could possibly cover a majority of all those situations dealing with a need of *factual knowledge* that a student can encounter during all his school years. However, this useful knowledge is not possibly organized and presented currently in *the most optimal form* to support independent cumulative adoption of knowledge that addresses the student's previous knowledge and personal needs as well as to help identifying the most essential content for current learning topic and to encourage inductive and deductive reasoning with sufficiently spaced and repeated exposure and retention.

Therefore we think that there is a great *potential for education* in the knowledge contained already now in the Wikipedia but to enable better learning opportunities relying on the Wikipedia the research community should invest on more analysis about the properties of the Wikipedia and to develop computational methods that let to transform its knowledge to various forms of representation to address personalized educational needs of a student.

We hope that the proposed framework can open new possibilities for developing innovative methods of computer-assisted learning relying on knowledge structures managed with *small-world networks* (and possibly a *scale-free version of small-world network* being the most preferable), which is a compact efficient form that inherently emerges with many natural process including formation of the hyperlink structure of the Wikipedia. We suggest that personalization of learning activities can benefit from exploring collaboratively built and gradually updated free knowledge resources of the Wikipedia online encyclopedia that inherently offers diverse collection of hyperlinks defining conceptual relationships usable for varied pedagogic purposes. We think that the principle of *cumulatively expanding hyperlink networks* covering more and more linkage between concepts of gradually growing vocabulary can enable an efficient and intuitive way to explore and adopt new knowledge meaningfully as well as to develop new kind of educational games that can be extended to manage diverse content besides text like images, videos, and tasks with augmented reality and tracking kinetic activities.

We think that personalized learning experience is affected by many factors and it is often difficult to control them systematically and in many cases it is not even necessary. We think that the information processing in *human neural system* has an inherent challenge that we are constantly exposed to an arriving information flow that is so high that our own ability to react, to make synthesis and generate new innovative information remains relatively limited in comparison. Therefore we think that it is important to create new educational methods to assist every learner in *filtering most meaningful information* for personal development, making synthesis and generating new

information resources that can be shared for collective benefit. On the other hand we think that to manage in conceptualization, learning and adoption of new knowledge human neural system requires some kind of continuity, repetition and looping, and also these aspects should be addressed when developing new educational methods.

We also think that *guided learning activities* should support voluntary efforts and offer surprising inspiring experiences. To provide for large populations equal yet personalized opportunity to learn essential entities of knowledge and skills needed in current society we think that it is useful to develop supporting methods that have a systematic underlying *motivation and structure*. These support methods should especially provide students with learning skills that include ability to collect and critically synthesize information from various sources as well foster creativity and innovation.

We think that conceptual networks based on *scale-free small-world network* structure can be beneficial for presenting *educational knowledge* offering efficient and compact form to build, manage and explore information. We think that tailored sequential processes of exposure and retention of pieces of knowledge following theory of *spaced learning* can fruitfully support cumulative adoption of knowledge. We think that since educational needs for each learner are unique, different alternative approaches and perspectives to learning topic should be encouraged and this can be supported with *modular and adaptive properties* of the structure of learning material. We think that to enable cost-efficient generation of educational experiences in learning sessions in a form that suits inherent cognitive and psychological characteristics of memory and human mind good opportunities are offered by *learner-driven* but at the same time sufficiently guided exploration in conceptual networks. Since learning new knowledge about current learning topic can be typically seen to consist of modular conceptual components and they typically have varied levels of significance and familiarity we think that a natural and intuitive learning process can be implemented by guided cumulative expanding exploration in a conceptual network of vocabulary concerning current learning topic and which is linked to previous vocabulary of learner.

We think that for any kind of knowledge entities *computational methods* can enable building and maintaining networks that can be used to manage educational content and to explore connectivities of *knowledge entities* to adopt cumulatively vocabulary and conceptual relationships. We think that it is useful to offer to student various ways to customize learning experience in conceptual networks by letting to adjust the connectivity between relationships so that for example typically dominant highest-ranking relationships are temporarily hidden so that weaker but still important relationships instead become highlighted. We think that learners should have a possibility to explore knowledge resources with *diverse perspectives* addressing their personal needs and to actively express their creativity in many ways including adoption of new knowledge, building knowledge representations about their conceptualization and cumulatively modifying them in a collaborative process and also through activities that define new types of learning processes and games that can be actively shared and further iteratively refined in a learning community and in a surrounding society.

PART VI. Additional resources

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Appendix A

This doctoral dissertation is based on following eight publications P1-P8 which have been published in peer-reviewed conference proceedings between years 2009-2013, each supplied here with a short description.

P1: Lahti, L. (2009a). Assistive tool for collaborative learning of conceptual structures. Proc. 13th Human Computer Interaction International 2009, Part III (Universal Access in Human-Computer Interaction – Applications and Services), 19-24 July 2009, San Diego, CA, USA (ed. Stephanidis, C.). LNCS 5616, Springer, 53-62. Print ISBN 978-3-642-02712-3 and Online ISBN 978-3-642-02713-0. http://link.springer.com/chapter/10.1007/978-3-642-02713-0_6

In this publication we propose a new collaborative scheme to assist learning conceptual structures in a collaborative Web environment. We have implemented a prototype enabling collaborative ideation to build shared concept maps representing conceptualization of learners. We suggest supporting different collaborator roles to address personal needs of each learner participating in collaboration. We propose combining role-driven text-based parallel individual discussion chains that are illustrated cumulatively in a collaboratively agreed concept map.

Discussed in Chapter 4.

P2: Lahti, L. (2009b). Guided generation of pedagogical concept maps from the Wikipedia. Proc. World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education (E-Learn 2009). 26-30 October 2009, Vancouver, B.C., Canada (eds. Bastiaens, T. et al.). Association for the Advancement of Computing in Education (AACE), Chesapeake, Virginia, USA, 1741-1750. ISBN 1-880094-76-2. <http://www.editlib.org/p/32712>

In this publication we propose a new method for guided generation of concept maps from open access online knowledge from the Wikipedia online encyclopedia. Our method extracts semantic relations from sentences surrounding hyperlinks in the Wikipedia's articles and lets a learner to create customized learning objects in real-time based on collaborative recommendations considering her earlier knowledge.

Discussed in Chapter 5.

P3: Lahti, L. (2010a). Personalized learning paths based on Wikipedia article statistics. Proc. 2nd International Conference on Computer Supported Education (CSEDU 2010), 7–10 April 2010, Valencia, Spain (eds. Cordeiro, J. et al.), Vol. 1, 110-120. SciTePress, Institute for Systems and Technologies of Information, Control and Communication (INSTICC). ISBN 978-989-674-023-8. <http://dx.doi.org/10.5220/0002800901100120>

In this publication we propose a new semi-automated method for generating personalized learning paths from the Wikipedia online encyclopedia by following inter-article hyperlink chains based on various rankings that are retrieved from the statistics of the articles. Alternative perspectives for learning topics are achieved based on hierarchy of hyperlinks, repetition of hyperlink terms, article size, viewing rate, editing rate, or user-defined weighted mixture of them all enabling the learner to build independently concept maps following her needs and consideration.

Discussed in Chapter 6.

P4: Lahti, L. (2010b). Educational tool based on topology and evolution of hyperlinks in the Wikipedia. Proc. 10th IEEE International Conference on Advanced Learning Technologies (ICALT 2010), 5–7 July 2010, Sousse, Tunisia (eds. Jemni, M. et al.), 233-235. ISBN 978-0-7695-4055-9 and ISBN 978-1-4244-7144-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5571281

In this publication we propose a new method to support educational exploration in the hyperlink network of the Wikipedia online encyclopedia. This extends the method introduced in publication P3 in respect to three important new features: the learner can simultaneously operate with parallel

ranking lists of hyperlinks, the concept map construction emphasizes building diversely branching structures, and different consecutive temporal versions of Wikipedia articles can be browsed.

Discussed in Chapter 7.

P5: Lahti, L. (2011a). ConceptMapWiki – a collaborative framework for agglomerating pedagogical knowledge. Proc. 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), 6–8 July 2010, Athens, Georgia, USA (eds. Aedo, I. et al.), 163-165. Online ISBN 978-0-7695-4346-8 and Print ISBN 978-1-61284-209-7. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5992312

In this publication we propose a new educational framework, ConceptMapWiki, that is a wiki representing pedagogical knowledge with a collection of concept maps which is collaboratively created, edited and browsed. The learners and educators provide complementing contribution to evolving shared knowledge structures stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria. Pedagogically motivated learning paths can be collaboratively defined and evaluated, and educational games can be incorporated based on browsing and editing concept maps.

Discussed in Chapter 8.

P6: Lahti, L. (2011b). Educational concept mapping method based on high-frequency words and Wikipedia linkage. Proc. 4th International Conference on Internet Technologies and Applications (ITA11), 6–9 September 2011, Wrexham, North Wales, UK (eds. Grout, V. et al.). Glyndwr University, Wrexham, Wales, UK. ISBN 978-0-946881-68-0. <http://www.ita11.org/papers.html>; <http://www.ita11.org/detailedProgramme.html>; <http://www.lulu.com/shop/vic-grout-and-stuart-cunningham-and-denise-oram-and-rich-picking/proceedings-of-the-fourth-international-conference-on-internet-technologies-and-applications-ita-11/ebook/product-17431522.html>

In this publication we propose a new computational method to support the learner's knowledge adoption based on concept mapping relying on three perspectives: learner's knowledge, learning context and learning objective. Each perspective is represented by a learning concept network that is generated based on a set of high-frequency words from a representative text sample that are connected based on the shortest hyperlink chains between corresponding Wikipedia articles. The learner explores ranking-based routings connecting learning concept networks by expanding a concept map.

Discussed in Chapter 9.

P7: Lahti, L. (2012). Educational framework for adoption of vocabulary based on Wikipedia linkage and spaced learning. Proc. Global Learn 2012: Global Conference on Learning and Technology, online conference on 6 November 2012 (eds. Bastiaens, T., & Marks, G.), pp. 8-13. Association for the Advancement of Computing in Education (AACE). ISBN 1-880094-99-1. <http://www.editlib.org/p/42033/>

In this publication we propose a new educational framework relying on pedagogic conceptual network generated by linking the most essential concepts of learning topic based on the shortest connecting paths in hyperlink network of Wikipedia encyclopedia assisted with Wiktionary dictionary. To adopt vocabulary the learner traverses links of pedagogic conceptual network along learning path generated by method in sequential process having tailored variation and repetition computed based on theory of spaced learning. The learning path is shown to learner as sequence of compact relation statements extracted from sentences surrounding hyperlinks in Wikipedia articles, supplied with set of visualizations based on main verb identified in them.

Discussed in Chapter 12, starting from Subchapter 12.1.

P8: Lahti, L. (2013). Educational framework based on cumulative vocabularies, conceptual networks and Wikipedia linkage. Proc. London International Conference on Education (LICE 2013). 4-6 November 2013, London, UK (lisää toimittajat). ISBN 978-1-908320-16-2.

In this publication we propose a new educational framework relying on cumulative conceptual networks based on hyperlink network of the Wikipedia connecting concepts of vocabulary about current learning topic. Personalization of educational material is carried out by alternating the distribution of enabled hyperlinks connecting concepts belonging to current vocabulary. Adoption of knowledge can be gained by exploring hyperlink network and the shortest paths between concepts of vocabulary (especially concepts having highest rankings and strongly rising rankings). Publication also estimates properties of conceptual networks generated based on hyperlink network of the Wikipedia between concepts retrieved from English Vocabulary Profile for cumulatively growing vocabularies corresponding to six language ability levels. Discussed in Chapter 12, starting from Subchapter 12.2.

P9: Lahti, L. (2014). Educational exploration based on conceptual networks generated by students and Wikipedia linkage. Proc. World Conference on Educational Multimedia, Hypermedia and Telecommunications 2014 (EdMedia 2014) (lisää toimittajat), 964–974. ISBN 978-1-939797-08-7. Association for the Advancement of Computing in Education (AACE), Chesapeake, VA, USA. <http://www.editlib.org/p/147608/>

In this publication we propose a new educational framework for educational exploration based on conceptual networks generated and explored by students supplied with Wikipedia linkage. We report findings based on comparison of word lists and conceptual networks generated by students, vocabulary ranking of British National Corpus, hyperlink network structure of the Wikipedia and exploration paths of students in the hyperlink network of the Wikipedia. Publication introduces sample high-frequency lists and conceptual relationships generated by students and comparison of rankings. Publication extends the analysis introduced in publications P2 and P6 in respect to comparison of features of concept maps drawn by students, hyperlink network structure of the Wikipedia and exploration paths in hyperlink network of the Wikipedia. Discussed in Subchapters 3.9-3.10, Subchapters 5.3-5.4, Subchapter 9.3 and Subchapter 10.2.

Appendix B

Main themes of our research can be explained by formulating a list of questions, with an aim to find suitable balance between broad coverage and specific attention to details.

1. How learners could be fruitfully combined into *collaborative educational groups* complementing each other's strengths and contributions with a system supporting computer-assisted learning? How the collaborator roles can be easily identified, distributed and supported with the automated system? How *collaborative learning efforts can be cumulated into a shared visualization* representing agreed conceptualization? How negotiation and ideation (brainstorming) between participating learners representing complementing collaborator roles can be organized in a systematic well documented and referenced way?
2. How knowledge content and its structures collaboratively created and edited in open access knowledge resources could be exploited in computer-assisted learning? Especially *how to exploit the extensive resources of the Wikipedia online encyclopedia* being currently the largest encyclopedia available? How the learner could be provided with fruitful *personalized support by getting recommendations how to pedagogically explore knowledge resources*? How the learner could cumulatively build own visual representations of the knowledge explored so far? Especially how to visualize explorations with concept maps due to their compactness and expressiveness?
3. How the learner's *exploration in knowledge resource of the Wikipedia* could be fruitfully *personalized and tailored based on simple statistical features* already present in knowledge content and its structures? How recommendations could be generated based on a compact set of diverse features reflecting important characteristics of learning process? How this exploration can be represented and visualized fluently in a compact and intuitive way using concept maps?
4. How the learner could build concept maps representing *diverse exploration paths in the knowledge resources of the Wikipedia* exploiting possibilities of simultaneously operating with *parallel ranking lists of hyperlinks*, emphasizing in the concept map construction building diversely branching structures, and browsing different *consecutive temporal versions* of Wikipedia articles?
5. How a new educational framework could be defined to support the community of learners to generate together a *wiki representing pedagogical knowledge with a collection of concept maps* which is collaboratively created, edited and browsed? How the learners and educators could provide complementing contribution to evolving shared knowledge structures stored supplied with time stamps and a user profile enabling to analyze maturing of knowledge according to various learner-driven criteria? How *pedagogically motivated learning paths can be collaboratively defined and evaluated*, and how educational games can be incorporated based on browsing and editing a concept map collection?
6. How the process of adoption of new knowledge by the learner could be best supported in connecting the learner's prior knowledge fruitfully to new knowledge? How the *knowledge resource of the Wikipedia* and its knowledge structures could be exploited *to provide efficient linking between prior and new knowledge*? How the *learning context* and the *collective cumulative knowledge of the learner community* could provide diverse supporting guidance for adoption of new knowledge? How this learning process could be intuitively visualized?
7. How the learner's *exploration in hyperlink network of the Wikipedia as a sequential process* could be guided pedagogically rewardingly to adopt vocabulary and new knowledge? How this sequential process could be best *supported with tailored variation and repetition* addressing functional principles of living neural system and memory? What are the most *optimal spacing intervals for exposure and retention of pieces of knowledge to be learned*? What kind of parameters are useful to be taken into account when trying to optimize the adoption of knowledge and how these parameters could be well measured and adjusted?

8. How educational material could be presented to the student with a personalized and cumulative form that well supports *adoption of vocabulary and new knowledge*? How the connectivity of conceptual network can be flexibly alternated along learning to offer gradually expanding coverage of vocabulary? What kind of empirical estimates can be made about properties of cumulative vocabularies and conceptual networks when a *learner goes through typical language ability levels*? What kind of *conceptual linkage and exploration patterns* can be generated *based on the Wikipedia hyperlink network* to represent conceptualization of an average child or adult?
9. How educational exploration could be supported based on conceptual networks generated and explored by students supplied with Wikipedia linkage? How methods of knowledge adoption could be supplied with features identified by *comparison of word lists and conceptual networks generated by students, vocabulary ranking of British National Corpus, hyperlink network structure of the Wikipedia and exploration paths of students in the hyperlink network of the Wikipedia*? How learning could benefit from introduction of sample high-frequency lists and conceptual relationships generated by students and comparison of rankings?

We have tried to formulate these questions so that in the given order they form a continuity and open gradually enriching perspectives to our research of developing computer-assisted learning. These questions one by one become under focus in publications [P1]-[P9], thus publication [P1] trying to address question 1, publication [P2] question 2, and so on.

Appendix C

Based on Table 4.2 this listing shows the number of occurrences (measured proportionally) of twelve activities among four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20), and also the sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally).

In the listing below, for example for member IB_1 the number of occurrences (measured proportionally) of activity “submit ideas” is 0.025806. This is calculated based on Table 4.2 so that since for member IB_1 the number of occurrences of activity “submit ideas” is 4 and the sum of the number of occurrences of activity “submit ideas” for all 20 members together is 155 (29+27+54+45 = 155), then $4/155 \approx 0.025806$.

Members belonging to groups of Competing Values Framework collaborator roles	Activities 1-6 of twelve activities					
Innovator-broker (create)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
IB_1	0.025806	0.044444	0.052326	0.085714	0.015152	0.02381
IB_2	0.03871	0.037037	0.02907	0.057143	0.030303	0.02381
IB_3	0.051613	0.051852	0.046512	0.028571	0.045455	0.035714
IB_4	0.025806	0.02963	0.02907	0	0.030303	0.011905
IB_5	0.045161	0.066667	0.075581	0.142857	0.060606	0.02381
Producer-director (compete)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
PD_1	0.019355	0.02963	0.023256	0.057143	0.030303	0.02381
PD_2	0.032258	0.074074	0.075581	0	0.090909	0.02381
PD_3	0.032258	0.044444	0.02907	0.142857	0.045455	0.059524
PD_4	0.03871	0.051852	0.046512	0	0.060606	0.047619
PD_5	0.051613	0.022222	0.02907	0.057143	0.030303	0.047619
Coordinator-monitor (control)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
CM_1	0.012903	0.044444	0.034884	0.028571	0.015152	0.071429
CM_2	0.090323	0.051852	0.040698	0.057143	0.015152	0.095238
CM_3	0.116129	0.044444	0.093023	0.028571	0.121212	0.035714
CM_4	0.045161	0.066667	0.069767	0.057143	0.090909	0.107143
CM_5	0.083871	0.02963	0.040698	0.028571	0.060606	0.047619
Facilitator-mentor (collaborate)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
FM_1	0.051613	0.074074	0.046512	0.142857	0.045455	0.047619
FM_2	0.070968	0.051852	0.052326	0.028571	0.030303	0.083333
FM_3	0.058065	0.059259	0.063953	0.057143	0.075758	0.071429
FM_4	0.064516	0.066667	0.069767	0	0.045455	0.047619
FM_5	0.045161	0.059259	0.052326	0	0.060606	0.071429

Members belonging to groups of Competing Values Framework collaborator roles	Activities 7-12 of twelve activities					
Innovator-broker (create)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
IB_1	0.011765	0.02	0.04886	0	0	0.027778
IB_2	0.047059	0.044	0.032573	0	0.017241	0.111111
IB_3	0.035294	0.048	0.04886	0	0.034483	0.027778
IB_4	0.035294	0.024	0.029316	0	0.034483	0.055556
IB_5	0.047059	0.032	0.071661	0.222222	0.017241	0.055556
Producer-director (compete)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
PD_1	0.047059	0.02	0.026059	0	0	0.027778
PD_2	0.082353	0.044	0.074919	0.222222	0.051724	0.083333
PD_3	0.047059	0.048	0.035831	0	0.396552	0.055556
PD_4	0.070588	0.052	0.04886	0	0.034483	0
PD_5	0.047059	0.056	0.026059	0.111111	0.017241	0.083333
Coordinator-monitor (control)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
CM_1	0.035294	0.04	0.039088	0	0.017241	0
CM_2	0.011765	0.1	0.045603	0.111111	0.034483	0.166667
CM_3	0.094118	0.084	0.071661	0.111111	0.017241	0
CM_4	0.094118	0.068	0.068404	0	0	0
CM_5	0.047059	0.068	0.035831	0.111111	0.12069	0.027778
Facilitator-mentor (collaborate)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
FM_1	0.058824	0.048	0.058632	0	0.017241	0.055556
FM_2	0.023529	0.048	0.052117	0	0	0.027778
FM_3	0.058824	0.06	0.061889	0	0.155172	0.111111
FM_4	0.047059	0.052	0.068404	0	0.034483	0.055556
FM_5	0.058824	0.044	0.055375	0.111111	0	0.027778
Members belonging to groups of Competing Values Framework collaborator roles						
Innovator-broker (create)	Sum of number of occurrences of all activities (activities 1-12) of current member (proportionally)					

IB_1	0.355654					
IB_2	0.468056					
IB_3	0.454131					
IB_4	0.305362					
IB_5	0.860421					
Producer-director (compete)	Sum of number of occurrences of all activities (activities 1-12) of current member (proportionally)					
PD_1	0.304391					
PD_2	0.855183					
PD_3	0.936604					
PD_4	0.451229					
PD_5	0.578773					
Coordinator-monitor (control)	Sum of number of occurrences of all activities (activities 1-12) of current member (proportionally)					
CM_1	0.339006					
CM_2	0.820032					
CM_3	0.817226					
CM_4	0.667312					
CM_5	0.701463					
Facilitator-mentor (collaborate)	Sum of number of occurrences of all activities (activities 1-12) of current member (proportionally)					
FM_1	0.646382					
FM_2	0.468777					
FM_3	0.832603					
FM_4	0.551525					
FM_5	0.585868					

Appendix D

Based on Table 4.2 this listing shows the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role in respect to four collaborator roles of Competing Values Framework so that each role represented by five persons (n=20).

In the listing below, for example for member IB_1 the activity frequency (measured proportionally) of activity “submit ideas” is 0.025806 as explained in introductory text of Appendix C. On the other hand corresponding empirically gained average activity frequency (measured proportionally) for members of the same collaborator role of Innovator-broker is 0.187096774 (based on Table 4.2 it can computed as $29/(29+27+54+45) \approx 0.187096774$ that is the number of occurrences of activity “submit ideas” for five members of role Innovator-broker divided by the number of occurrences of activity “submit ideas” for twenty members of all four roles). Thus for member IB_1 the absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role is about absolute value of 0.025806 minus 0.187096774 that is about 0.161290323.

Members belonging to groups of Competing Values Framework collaborator roles	Activities 1-6 of twelve activities					
Innovator-broker (create)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
IB_1	0.161290323	0.185185185	0.180232558	0.228571429	0.166666667	0.095238095
IB_2	0.148387097	0.192592593	0.203488372	0.257142857	0.151515152	0.095238095
IB_3	0.135483871	0.177777778	0.186046512	0.285714286	0.136363636	0.083333333
IB_4	0.161290323	0.2	0.203488372	0.314285714	0.151515152	0.107142857
IB_5	0.141935484	0.162962963	0.156976744	0.171428571	0.121212121	0.095238095
Producer-director (compete)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
PD_1	0.15483871	0.192592593	0.180232558	0.2	0.227272727	0.178571429
PD_2	0.141935484	0.148148148	0.127906977	0.257142857	0.166666667	0.178571429
PD_3	0.141935484	0.177777778	0.174418605	0.114285714	0.212121212	0.142857143
PD_4	0.135483871	0.17037037	0.156976744	0.257142857	0.196969697	0.154761905
PD_5	0.122580645	0.2	0.174418605	0.2	0.227272727	0.154761905
Coordinator-monitor (control)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
CM_1	0.335483871	0.192592593	0.244186047	0.171428571	0.287878788	0.285714286
CM_2	0.258064516	0.185185185	0.238372093	0.142857143	0.287878788	0.261904762
CM_3	0.232258065	0.192592593	0.186046512	0.171428571	0.181818182	0.321428571
CM_4	0.303225806	0.17037037	0.209302326	0.142857143	0.212121212	0.25
CM_5	0.26451	0.2074074	0.23837209	0.171428571	0.242424242	0.30952381

	6129	07	3			
Facilitator-mentor (collaborate)	Submits ideas	Adds nodes to concept map	Adds arcs to concept map	Makes references to ideas	Makes references to concept map	Comments ideas
FM_1	0.238709677	0.237037037	0.238372093	0.085714286	0.212121212	0.273809524
FM_2	0.219354839	0.259259259	0.23255814	0.2	0.227272727	0.238095238
FM_3	0.232258065	0.251851852	0.220930233	0.171428571	0.181818182	0.25
FM_4	0.225806452	0.244444444	0.215116279	0.228571429	0.212121212	0.273809524
FM_5	0.24516129	0.251851852	0.23255814	0.228571429	0.196969697	0.25
Members belonging to groups of Competing Values Framework collaborator roles	Activities 7-12 of twelve activities					
Innovator-broker (create)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
IB_1	0.164705882	0.148	0.182410423	0.222222222	0.103448276	0.25
IB_2	0.12941765	0.124	0.198697068	0.222222222	0.086206897	0.166666667
IB_3	0.141176471	0.12	0.182410423	0.222222222	0.068965517	0.25
IB_4	0.141176471	0.144	0.201954397	0.222222222	0.068965517	0.222222222
IB_5	0.12941765	0.136	0.159609121	0	0.086206897	0.222222222
Producer-director (compete)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
PD_1	0.247058824	0.2	0.185667752	0.333333333	0.5	0.222222222
PD_2	0.211764706	0.176	0.136807818	0.111111111	0.448275862	0.166666667
PD_3	0.247058824	0.172	0.175895765	0.333333333	0.103448276	0.194444444
PD_4	0.223529412	0.168	0.16286645	0.333333333	0.465517241	0.25
PD_5	0.247058824	0.164	0.185667752	0.222222222	0.482758621	0.166666667
Coordinator-monitor (control)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
CM_1	0.247058824	0.32	0.221498371	0.333333333	0.172413793	0.194444444
CM_2	0.270588235	0.26	0.214983713	0.222222222	0.155172414	0.027777778
CM_3	0.188235294	0.276	0.188925081	0.222222222	0.172413793	0.194444444
CM_4	0.188235294	0.292	0.19218241	0.333333333	0.189655172	0.194444444
CM_5	0.235294118	0.292	0.2247557	0.222222222	0.068965517	0.166666667
Facilitator-mentor (collaborate)	Comments concept map	Sends coordination messages	Synthesizes ideas to concept map	Distributes topics from concept map for reconsideration	Explores accordance of ideas and concept map	Requests stimulation for creative thinking
FM_1	0.188235294	0.204	0.237785016	0.111111111	0.189655172	0.222222222

FM_2	0.22352 9412	0.204	0.24429967 4	0.111111111	0.206896552	0.25
FM_3	0.18823 5294	0.192	0.23452768 7	0.111111111	0.051724138	0.166666667
FM_4	0.2	0.2	0.22801302 9	0.111111111	0.172413793	0.222222222
FM_5	0.18823 5294	0.208	0.24104234 5	0	0.206896552	0.25

Each absolute value of difference from listing above for each member was coupled with the sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally) shown in listing of Appendix C. Thus we gained 240 pairs of values that are shown in two listings below in both original ordering and in such ordering that each pair of values is sorted in ascending order based on the absolute value of difference.

In the former of two listings absolute values of difference are listed one activity at time (activities 1-12) for all twenty members in order Innovator-broker, Producer-director, Coordinator-monitor and Facilitator-mentor for each member 1-5. The latter of two listings is illustrated in Figure 4.4.

Each pair of values in original ordering		When each pair of values is sorted into ascending order based on the absolute value of difference			
The absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role	The sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally)		Rank	The absolute value of difference between activity frequency of current member and corresponding empirically gained average activity frequency for members of the same collaborator role	The sum of number of occurrences of all activities (activities 1-12) of current member (measured proportionally)
0.16129	0.355654		1	0	0.860421
0.148387	0.468056		2	0	0.585868
0.135484	0.454131		3	0.027778	0.820032
0.16129	0.305362		4	0.051724	0.832603
0.141935	0.860421		5	0.068966	0.454131
0.154839	0.304391		6	0.068966	0.305362
0.141935	0.855183		7	0.068966	0.701463
0.141935	0.936604		8	0.083333	0.454131
0.135484	0.451229		9	0.085714	0.646382
0.122581	0.578773		10	0.086207	0.468056
0.335484	0.339006		11	0.086207	0.860421
0.258065	0.820032		12	0.095238	0.355654
0.232258	0.817226		13	0.095238	0.468056
0.303226	0.667312		14	0.095238	0.860421
0.264516	0.701463		15	0.103448	0.936604
0.23871	0.646382		16	0.103448	0.355654
0.219355	0.468777		17	0.107143	0.305362
0.232258	0.832603		18	0.111111	0.855183
0.225806	0.551525		19	0.111111	0.646382
0.245161	0.585868		20	0.111111	0.468777
0.185185	0.355654		21	0.111111	0.832603
0.192593	0.468056		22	0.111111	0.551525

0.177778	0.454131		23	0.114286	0.936604
0.2	0.305362		24	0.12	0.454131
0.162963	0.860421		25	0.121212	0.860421
0.192593	0.304391		26	0.122581	0.578773
0.148148	0.855183		27	0.124	0.468056
0.177778	0.936604		28	0.127907	0.855183
0.17037	0.451229		29	0.129412	0.468056
0.2	0.578773		30	0.129412	0.860421
0.192593	0.339006		31	0.135484	0.454131
0.185185	0.820032		32	0.135484	0.451229
0.192593	0.817226		33	0.136	0.860421
0.17037	0.667312		34	0.136364	0.454131
0.207407	0.701463		35	0.136808	0.855183
0.237037	0.646382		36	0.141176	0.454131
0.259259	0.468777		37	0.141176	0.305362
0.251852	0.832603		38	0.141935	0.860421
0.244444	0.551525		39	0.141935	0.855183
0.251852	0.585868		40	0.141935	0.936604
0.180233	0.355654		41	0.142857	0.936604
0.203488	0.468056		42	0.142857	0.820032
0.186047	0.454131		43	0.142857	0.667312
0.203488	0.305362		44	0.144	0.305362
0.156977	0.860421		45	0.148	0.355654
0.180233	0.304391		46	0.148148	0.855183
0.127907	0.855183		47	0.148387	0.468056
0.174419	0.936604		48	0.151515	0.468056
0.156977	0.451229		49	0.151515	0.305362
0.174419	0.578773		50	0.154762	0.451229
0.244186	0.339006		51	0.154762	0.578773
0.238372	0.820032		52	0.154839	0.304391
0.186047	0.817226		53	0.155172	0.820032
0.209302	0.667312		54	0.156977	0.860421
0.238372	0.701463		55	0.156977	0.451229
0.238372	0.646382		56	0.159609	0.860421
0.232558	0.468777		57	0.16129	0.355654
0.22093	0.832603		58	0.16129	0.305362
0.215116	0.551525		59	0.162866	0.451229
0.232558	0.585868		60	0.162963	0.860421
0.228571	0.355654		61	0.164	0.578773
0.257143	0.468056		62	0.164706	0.355654
0.285714	0.454131		63	0.166667	0.855183
0.314286	0.305362		64	0.166667	0.355654
0.171429	0.860421		65	0.166667	0.468056
0.2	0.304391		66	0.166667	0.855183
0.257143	0.855183		67	0.166667	0.578773
0.114286	0.936604		68	0.166667	0.701463

0.257143	0.451229		69	0.166667	0.832603
0.2	0.578773		70	0.168	0.451229
0.171429	0.339006		71	0.17037	0.451229
0.142857	0.820032		72	0.17037	0.667312
0.171429	0.817226		73	0.171429	0.860421
0.142857	0.667312		74	0.171429	0.339006
0.171429	0.701463		75	0.171429	0.817226
0.085714	0.646382		76	0.171429	0.701463
0.2	0.468777		77	0.171429	0.832603
0.171429	0.832603		78	0.172	0.936604
0.228571	0.551525		79	0.172414	0.339006
0.228571	0.585868		80	0.172414	0.817226
0.166667	0.355654		81	0.172414	0.551525
0.151515	0.468056		82	0.174419	0.936604
0.136364	0.454131		83	0.174419	0.578773
0.151515	0.305362		84	0.175896	0.936604
0.121212	0.860421		85	0.176	0.855183
0.227273	0.304391		86	0.177778	0.936604
0.166667	0.855183		87	0.177778	0.454131
0.212121	0.936604		88	0.178571	0.304391
0.19697	0.451229		89	0.178571	0.855183
0.227273	0.578773		90	0.180233	0.355654
0.287879	0.339006		91	0.180233	0.304391
0.287879	0.820032		92	0.181818	0.817226
0.181818	0.817226		93	0.181818	0.832603
0.212121	0.667312		94	0.18241	0.355654
0.242424	0.701463		95	0.18241	0.454131
0.212121	0.646382		96	0.185185	0.355654
0.227273	0.468777		97	0.185185	0.820032
0.181818	0.832603		98	0.185668	0.304391
0.212121	0.551525		99	0.185668	0.578773
0.19697	0.585868		100	0.186047	0.454131
0.095238	0.355654		101	0.186047	0.817226
0.095238	0.468056		102	0.188235	0.817226
0.083333	0.454131		103	0.188235	0.667312
0.107143	0.305362		104	0.188235	0.646382
0.095238	0.860421		105	0.188235	0.832603
0.178571	0.304391		106	0.188235	0.585868
0.178571	0.855183		107	0.188925	0.817226
0.142857	0.936604		108	0.189655	0.667312
0.154762	0.451229		109	0.189655	0.646382
0.154762	0.578773		110	0.192	0.832603
0.285714	0.339006		111	0.192182	0.667312
0.261905	0.820032		112	0.192593	0.468056
0.321429	0.817226		113	0.192593	0.304391
0.25	0.667312		114	0.192593	0.339006

0.309524	0.701463		115	0.192593	0.817226
0.27381	0.646382		116	0.194444	0.936604
0.238095	0.468777		117	0.194444	0.339006
0.25	0.832603		118	0.194444	0.817226
0.27381	0.551525		119	0.194444	0.667312
0.25	0.585868		120	0.19697	0.451229
0.164706	0.355654		121	0.19697	0.585868
0.129412	0.468056		122	0.198697	0.468056
0.141176	0.454131		123	0.2	0.578773
0.141176	0.305362		124	0.2	0.304391
0.129412	0.860421		125	0.2	0.578773
0.247059	0.304391		126	0.2	0.468777
0.211765	0.855183		127	0.2	0.305362
0.247059	0.936604		128	0.2	0.551525
0.223529	0.451229		129	0.2	0.304391
0.247059	0.578773		130	0.2	0.551525
0.247059	0.339006		131	0.201954	0.305362
0.270588	0.820032		132	0.203488	0.468056
0.188235	0.817226		133	0.203488	0.305362
0.188235	0.667312		134	0.204	0.646382
0.235294	0.701463		135	0.204	0.468777
0.188235	0.646382		136	0.206897	0.468777
0.223529	0.468777		137	0.206897	0.585868
0.188235	0.832603		138	0.207407	0.701463
0.2	0.551525		139	0.208	0.585868
0.188235	0.585868		140	0.209302	0.667312
0.148	0.355654		141	0.211765	0.855183
0.124	0.468056		142	0.212121	0.936604
0.12	0.454131		143	0.212121	0.646382
0.144	0.305362		144	0.212121	0.551525
0.136	0.860421		145	0.212121	0.667312
0.2	0.304391		146	0.214984	0.820032
0.176	0.855183		147	0.215116	0.551525
0.172	0.936604		148	0.219355	0.468777
0.168	0.451229		149	0.22093	0.832603
0.164	0.578773		150	0.221498	0.339006
0.32	0.339006		151	0.222222	0.355654
0.26	0.820032		152	0.222222	0.468056
0.276	0.817226		153	0.222222	0.454131
0.292	0.667312		154	0.222222	0.305362
0.292	0.701463		155	0.222222	0.578773
0.204	0.646382		156	0.222222	0.820032
0.204	0.468777		157	0.222222	0.817226
0.192	0.832603		158	0.222222	0.701463
0.2	0.551525		159	0.222222	0.304391
0.208	0.585868		160	0.222222	0.305362

0.18241	0.355654		161	0.222222	0.860421
0.198697	0.468056		162	0.222222	0.646382
0.18241	0.454131		163	0.222222	0.551525
0.201954	0.305362		164	0.223529	0.451229
0.159609	0.860421		165	0.223529	0.468777
0.185668	0.304391		166	0.224756	0.701463
0.136808	0.855183		167	0.225806	0.551525
0.175896	0.936604		168	0.227273	0.304391
0.162866	0.451229		169	0.227273	0.578773
0.185668	0.578773		170	0.227273	0.468777
0.221498	0.339006		171	0.228013	0.551525
0.214984	0.820032		172	0.228571	0.551525
0.188925	0.817226		173	0.228571	0.585868
0.192182	0.667312		174	0.228571	0.355654
0.224756	0.701463		175	0.232258	0.817226
0.237785	0.646382		176	0.232258	0.832603
0.2443	0.468777		177	0.232558	0.468777
0.234528	0.832603		178	0.232558	0.585868
0.228013	0.551525		179	0.234528	0.832603
0.241042	0.585868		180	0.235294	0.701463
0.222222	0.355654		181	0.237037	0.646382
0.222222	0.468056		182	0.237785	0.646382
0.222222	0.454131		183	0.238095	0.468777
0.222222	0.305362		184	0.238372	0.820032
0	0.860421		185	0.238372	0.701463
0.333333	0.304391		186	0.238372	0.646382
0.111111	0.855183		187	0.23871	0.646382
0.333333	0.936604		188	0.241042	0.585868
0.333333	0.451229		189	0.242424	0.701463
0.222222	0.578773		190	0.244186	0.339006
0.333333	0.339006		191	0.2443	0.468777
0.222222	0.820032		192	0.244444	0.551525
0.222222	0.817226		193	0.245161	0.585868
0.333333	0.667312		194	0.247059	0.304391
0.222222	0.701463		195	0.247059	0.936604
0.111111	0.646382		196	0.247059	0.578773
0.111111	0.468777		197	0.247059	0.339006
0.111111	0.832603		198	0.25	0.667312
0.111111	0.551525		199	0.25	0.832603
0	0.585868		200	0.25	0.585868
0.103448	0.355654		201	0.25	0.355654
0.086207	0.468056		202	0.25	0.454131
0.068966	0.454131		203	0.25	0.451229
0.068966	0.305362		204	0.25	0.468777
0.086207	0.860421		205	0.25	0.585868
0.5	0.304391		206	0.251852	0.832603

0.448276	0.855183		207	0.251852	0.585868
0.103448	0.936604		208	0.257143	0.468056
0.465517	0.451229		209	0.257143	0.855183
0.482759	0.578773		210	0.257143	0.451229
0.172414	0.339006		211	0.258065	0.820032
0.155172	0.820032		212	0.259259	0.468777
0.172414	0.817226		213	0.26	0.820032
0.189655	0.667312		214	0.261905	0.820032
0.068966	0.701463		215	0.264516	0.701463
0.189655	0.646382		216	0.270588	0.820032
0.206897	0.468777		217	0.27381	0.646382
0.051724	0.832603		218	0.27381	0.551525
0.172414	0.551525		219	0.276	0.817226
0.206897	0.585868		220	0.285714	0.454131
0.25	0.355654		221	0.285714	0.339006
0.166667	0.468056		222	0.287879	0.339006
0.25	0.454131		223	0.287879	0.820032
0.222222	0.305362		224	0.292	0.667312
0.222222	0.860421		225	0.292	0.701463
0.222222	0.304391		226	0.303226	0.667312
0.166667	0.855183		227	0.309524	0.701463
0.194444	0.936604		228	0.314286	0.305362
0.25	0.451229		229	0.32	0.339006
0.166667	0.578773		230	0.321429	0.817226
0.194444	0.339006		231	0.333333	0.304391
0.027778	0.820032		232	0.333333	0.936604
0.194444	0.817226		233	0.333333	0.451229
0.194444	0.667312		234	0.333333	0.339006
0.166667	0.701463		235	0.333333	0.667312
0.222222	0.646382		236	0.335484	0.339006
0.25	0.468777		237	0.448276	0.855183
0.166667	0.832603		238	0.465517	0.451229
0.222222	0.551525		239	0.482759	0.578773
0.25	0.585868		240	0.5	0.304391

Appendix E

This listing shows two alternatively computed high-frequency word lists of 110 highest-ranking common nouns of British National Corpus ((Kilgarriff 1997); (Leech et al. 2001)), relying on about 100 million word corpus, and similarly 110 highest-ranking common nouns of Corpus of Contemporary American English ((Davies & Gardner 2010); (Word frequency data from COCA 2013)), relying on about 400 million word corpus, that reveal together some variation in rankings of everyday vocabulary. We could not fully understand why in online frequency lists of Corpus of Contemporary American English some of the frequencies did not seem to systematically descend along the provided rank position but anyway we decided to use these lists for our analysis.

Rank position	Lemmatized words in British National Corpus (Kilgarriff 1997)		Lemmatized words in British National Corpus (Leech et al. 2001)		Lemmatized words in Corpus of Contemporary American English 2013 ((Davies & Gardner 2010); (Word frequency data from COCA 2013))	
	noun concept (rank among all words (including nouns and other part-of-speech))	frequency	noun concept (rank among all words (including nouns and other part-of-speech))	frequency per million words	noun concept (rank among all words (including nouns and other part-of-speech))	frequency
1	time (53)	183427	time (53)	1833	time (52)	764657
2	year (60)	163930	year (60)	1639	year (54)	769254
3	people (80)	125430	people (79)	1256	people (62)	691468
4	way (89)	112636	way (90)	1108	way (84)	470401
5	man (101)	97985	man (95)	1003	day (90)	432773
6	day (104)	92699	day (100)	940	man (94)	409760
7	thing (115)	77612	thing (111)	776	thing (97)	400724
8	child (121)	71008	child (121)	710	woman (111)	341422
9	government (133)	66894	mr (131)	673	life (114)	333085
10	part (135)	65773	government (132)	670	child (115)	333849
11	life (137)	64423	work (134)	653	world (123)	303506
12	case (140)	63577	life (138)	645	school (125)	304183
13	woman (141)	63087	woman (140)	631	state (137)	272193
14	work (146)	62248	system (146)	619	family (147)	243267
15	system (149)	61912	case (149)	613	student (157)	255047
16	group (155)	60689	part (150)	612	group (163)	229435
17	number (156)	60607	group (152)	607	country (166)	223138
18	world (161)	59094	number (153)	606	problem (171)	217728
19	area (162)	58449	world (156)	600	hand (174)	225247
20	course (164)	57776	house (158)	598	part (178)	207861
21	company (165)	57754	area (159)	585	place (181)	202427
22	problem (168)	56483	company (162)	579	case (186)	200773
23	service (173)	54468	problem (166)	565	week (188)	199268
24	hand (176)	53265	service (173)	549	company (189)	2033

						45
25	party (177)	52979	place (175)	534	system (191)	200175
26	school (181)	52227	hand (176)	532	program (194)	195985
27	place (184)	51537	party (178)	529	question (197)	192070
28	point (190)	49187	school (179)	529	work (199)	187533
29	house (191)	49022	country (187)	486	government (201)	191314
30	country (193)	48177	point (189)	484	number (204)	186005
31	week (196)	47512	week (194)	476	night (209)	184511
32	member (199)	47141	member (195)	471	mr (211)	188555
33	end (206)	45160	end (201)	458	point (212)	177481
34	word (213)	43750	state (210)	440	home (225)	170527
35	example (216)	43402	word (212)	438	water (227)	167666
36	family (218)	42773	family (217)	428	room (228)	172472
37	fact (220)	42241	fact (218)	426	mother (230)	169407
38	state (224)	41351	head (227)	402	area (231)	165812
39	percent (225)	41205	month (231)	398	money (233)	164794
40	home (235)	39850	side (232)	398	story (234)	163582
41	month (236)	39819	business (233)	394	fact (236)	164401
42	side (237)	39626	night (234)	393	month (237)	162685
43	night (238)	39315	eye (235)	392	lot (239)	169570
44	eye (240)	39192	home (239)	390	right (240)	163259
45	head (241)	39000	question (240)	390	study (241)	174069
46	information (242)	38656	information (242)	387	book (242)	154013
47	question (243)	38608	power (245)	385	eye (243)	169150
48	business (244)	38204	change (246) (per_cent shares same position and frequency as change according to (http://ucrel.lancs.ac.uk/bncfreq/lists/5_1_all_rank_noun.txt))	384	job (244)	154743
49	power (246)	37963	interest (250)	376	word (245)	152891
50	money (247)	37892	development (253)	375	business (247)	154468
51	change (248)	37884	money (254)	375	issue (248)	156417
52	interest (250)	37744	book (255)	374	side (249)	152559
53	order (251)	37736	water (256)	372	kind (250)	155032
54	book (252)	37675	other (259)	367	head (252)	160131
55	development (254)	37386	form (260)	365	house (258)	149251
56	room (259)	36360	room (261)	364	service (264)	146122
57	water (261)	35767	level (262)	360	friend (266)	142697
58	form (262)	35758	car (267)	353	father (268)	145051

59	car (263)	35295	council (271)	348	power (272)	1413 57
60	other (264)	35164	policy (272)	348	hour (273)	1389 55
61	level (268)	34885	market (274)	346	game (274)	1463 11
62	policy (271)	34775	court (277)	344	line (277)	1359 86
63	council (274)	34496	effect (285)	336	end (279)	1341 04
64	line (278)	33888	result (287)	334	member (286)	1347 31
65	need (280)	33660	idea (292)	328	law (288)	1337 06
66	effect (281)	33423	use (293)	328	car (290)	1335 71
67	use (283)	32998	study (294)	327	city (291)	1326 84
68	idea (286)	32798	job (296) name (296)	326 326	community (297)	1330 57
69	study (287)	32786			name (299)	1271 39
70	lot (288)	32733	body (299)	325	president (304)	1342 03
71	job (290)	32484	report (300)	325	team (308)	1314 89
72	name (292)	32309	line (301)	323	minute (309)	1266 60
73	result (293)	32259	law (302)	318	idea (312)	1221 40
74	body (294)	32231	face (305)	315	kid (313)	1264 28
75	friend (296)	31927	friend (306)	315	body (314)	1251 65
76	right (297)	31873	authority (308)	313	information (315)	1273 31
77	authority (303)	31231	road (309)	313	back (323)	1250 06
78	view (306)	31102	minister (319)	305	parent (328)	1196 10
79	report (311)	30857	rate (323)	303	face (331)	1272 91
80	bit (315)	30675	door (324) hour (324)	302 302	others (337)	1157 71
81	face (316)	30624			level (339)	1217 04
82	market (318)	30596	office (329)	300	office (342)	1147 91
83	hour (324)	30218	right (330)	299	door (344)	1249 93
84	rate (325)	30179	war (331)	297	health (345)	1177 62
85	law (326)	30169	mother (332)	295	person (346)	1136 50
86	door (327)	30166	person (335)	290	art (347)	1178 51
87	court (328)	29976	reason (337)	289	war (350)	1178 04
88	office (329)	29943	view (338)	289	history (351)	1149 04
89	war (331)	29722	term (343)	288	party (352)	1129 62
90	reason (333)	29194	period (352)	283	result (355)	1162 77
91	minister (335)	29141	centre (353)	282	change (357)	1124 26
92	subject (336)	29091	figure (354) society (354)	282 282	morning (358)	1140 02
93	person (337)	28981			reason (360)	1068 63
94	term (338)	28896	police (356)	278	research (363)	1148 02
95	sort (342)	28760	city (359)	275	girl (364)	1104 09
96	period (348)	28300	need (362)	273	guy (365)	1104 09
97	society (352)	28150	community (364)	272	food (367)	1077

			million (364)	272		28
98	process (353)	28035			moment (369)	1097 20
99	mother (354)	27784	kind (367)	271	air (371)	1059 32
100	voice (357)	27665	price (368)	271	teacher (372)	1161 00
101	police (360)	27508	control (369)	270	force (373)	1080 05
102	kind (361)	27485	action (370) cost (370) issue (370) process (370)	269 269 269 269	education (377)	1137 31
103	price (369)	27166			foot (381)	1072 85
104	action (371)	26894			boy (383)	1074 47
105	issue (372)	26889			age (387)	1034 02
106	position (375)	26625	position (376)	268	policy (389)	1076 01
107	cost (377)	26556	course (377)	267	process (392)	1073 41
108	matter (379)	26304	minute (378)	266	music (393)	1026 57
109	community (380)	26289	education (383)	260	market (403)	1004 35
110	figure (382)	26191	type (385)	259	sense (408)	9589 6

Appendix F

This listing shows 102 core concepts of concept maps drawn by students and the closest matching entry of Wikipedia article corresponding to the concept (based on 102 highest-ranking concepts in word lists generated by students as discussed in Subchapter 3.10). Although according to this listing concept “sister” mentioned in concept maps corresponds to Wikipedia article Sibling it needs to be noted that also concept “brother” mentioned in concept maps (but not belonging to these 102 highest-ranking concepts) corresponds to the same Wikipedia article Sibling. In the Wikipedia both entry Sister and entry Brother are redirected to shared article Sibling and thus in the Wikipedia word “sibling” can be considered to represent both words “brother” and “sister”.

When analyzing conceptual relationships between 102 core concepts we made a decision to form a collection of altogether 145 conceptual relationships, called core relationships, aiming to represent knowledge structures of the students between 102 core concepts extended with concept “brother”. When comparing drawn concept maps to hyperlink structure of the Wikipedia, for example in Appendix N, concepts of concept maps can be transformed to a spelling that matches corresponding Wikipedia articles and thus concept “brother” can be transformed to a spelling that is Sibling.

<i>Concept in concept maps drawn by students</i>	<i>Original Finnish spelling of concept in concept maps drawn by students</i>	<i>The closest matching entry of Wikipedia article corresponding to the concept</i>
air	ilma	Atmosphere_of_Earth
animal	eläin	Animal
baby	vauva	Infant
bed	sänky	Bed
biology	biologia	Biology
birth	syntymä	Birth
book	kirja	Book
bread	leipä	Bread
car	auto	Automobile
cat	kissa	Cat
chair	tuoli	Chair
child	lapsi	Child
childhood	lapsuus	Childhood
city	kaupunki	City
clock	kello	Clock
cloth	vaate (in exploration task replaced with: vaatetus)	Clothing
computer	tietokone	Computer
death	kuolema	Death
disease	sairaus	Disease
dog	koira	Dog
dream (sleeping)	uni	Dream
eating	syöminen	Eating
education	koulutus	Education
elderness	vanhuus	Old_age
emotion	tunne	Emotion
environment	ympäristö	Environment
evolution	evoluutio	Evolution
exam	koe	Test_(assessment)
experience	kokemus	Experience
family	perhe	Family
father	isä	Father
flower	kukka	Flower
food	ruoka	Food
forest	metsä	Forest
freetime	vapaa-aika	Leisure
friend	ystävä (in exploration task replaced with: ystävyys)	Friendship
fun	hupi	Fun
future	tulevaisuus	Future
goal (to_achieve)	tavoite	Goal
god	jumala	God
goodness	hyvyys	Goodness
ground	maa	Ground

growing	kasvaminen	Growing
happiness	onnellisuus	Happiness
hate	viha	Hatred
health	terveys	Health
heart	sydän	Heart
hobby	harrastus	Hobby
holiday	loma	Holiday
home	koti	Home
hospital	sairaala	Hospital
house	talo	House
human	ihminen	Human
joy	ilo	Joy
learning	oppiminen	Learning
light	valo	Light
living	eläminen	Living
love	rakkaus	Love
marriage	avioliitto	Marriage
money	raha	Money
mother	äiti	Mother
music	musiikki	Music
nature	luonto	Nature
nutriment	ravinto	Diet (nutrition)
organism	eliö	Organism
oxygen	happi	Oxygen
paper	paperi	Paper
parent	vanhempi	Parent
party	juhla	Party
peace	rauha	Peace
pen	kynä	Pen
people	ihminen (ryhmä)	People
pet	lemmikki (in exploration task replaced with: lemmikkieläin)	Pet
philosophy	filosofia	Philosophy
phone	puhelin	Telephone
physical training	liikunta	Physical fitness
plant	kasvi	Plant
pleasure	nautinto	Pleasure
purpose	tarkoitus	Purpose
rain	sade	Rain
religion	uskonto	Religion
sadness	surullisuus	Sadness
school	koulu	School
sea	meri	Sea
shoe	kenkä	Shoe
sister	sisko (in exploration task replaced with: sisarus)	Sibling
sorrow	suru	Sorrow
sport	urheilu	Sport
study	opiskelu	Study
succeeding	onnistuminen	Management
summer	kesä	Summer
sun	aurinko	Sun
teacher	opettaja	Teacher
television	televisio	Television
time	aika	Time
travel	matka (in exploratio task replaced with: matkustaminen)	Travel
tree	puu	Tree
war	sota	War
water	vesi	Water
work	työ	Work
world	maailma	World
young_(person)	nuori (in exploration task replaced with: nuoruus)	Adolescence

Appendix G

Number of unique start concepts and unique end concepts as well as unique start/end concepts for hyperlinks between Wikipedia articles (as of in the beginning of March 2008), especially among 102 core concepts and considering hyperlinks departing from full text section and intro text section. In column 6 and column 9 that show “number of unique start/end concepts” each concept is counted only once even if occurring as both start and end concept.

Observed concept	Number of unique end concepts for hyperlinks departing from full text section of observed concept	Number of unique end concepts for hyperlinks departing from only intro text section of observed concept	Number of unique end concepts for hyperlinks departing from full text section of observed concept to any of 102 core concepts	Number of unique start concepts for hyperlinks arriving from full text section of any of 102 core concepts to observed concept	Number of unique start/end concepts for such hyperlinks that either arrive from full text section of any of 102 core concepts to observed concept or depart from full text section of observed concept to any of 102 core concepts	Number of unique end concepts for hyperlinks departing from only intro text section of observed concept to any of 102 core concepts	Number of unique start concepts for hyperlinks arriving from only intro text section of any of 102 core concepts to observed concept	Number of unique start/end concepts for such hyperlinks that either arrive from only intro text section of any of 102 core concepts to observed concept or depart from only intro text section of observed concept to any of 102 core concepts
Adolescence	190	6	7	8	10	1	0	1
Animal	245	13	10	10	15	2	3	5
Atmosphere of Earth	194	20	9	4	9	2	0	2
Automobile	709	5	1	3	3	0	0	0
Bed	161	15	3	1	3	0	0	0
Biology	305	19	9	11	13	1	3	3
Birth	64	9	4	1	5	2	1	3
Book	315	17	2	2	3	1	0	1
Bread	451	30	4	1	4	2	0	2
Cat	457	25	3	2	3	1	0	1
Chair	78	11	0	0	0	0	0	0
Child	102	3	9	7	10	1	2	3
Childhood	66	5	4	6	6	2	1	3
City	425	10	3	1	4	0	0	0
Clock	391	9	3	2	3	1	0	1
Clothing	212	36	4	3	6	1	0	1
Computer	459	18	2	2	4	0	0	0
Death	323	14	9	7	14	2	2	3
Diet (nutrition)	59	11	4	5	7	4	0	4
Disease	184	18	1	5	5	1	2	2
Dog	452	17	3	2	3	1	1	1
Dream	186	4	2	1	2	0	0	0
Eating	53	16	5	3	7	5	2	6
Education	254	16	13	9	17	2	4	5
Emotion	210	5	8	7	10	2	2	4
Environment	19	no intro text section available	0	0	0	no intro text section available	0	0
Evolution	419	26	5	11	14	1	2	2
Experience	237	25	2	3	5	0	3	3
Family	152	6	6	12	12	1	5	5
Father	92	30	6	5	7	3	2	3
Flower	221	5	2	2	3	0	0	0
Food	343	18	12	5	14	1	1	1
Forest	146	12	4	2	4	1	0	1

Friendship	103	45	4	1	4	1	0	1
Fun	1	no intro text section available	0	0	0	no intro text section available	0	0
Future	151	no intro text section available	7	2	7	no intro text section available	0	0
Goal	42	5	1	2	2	0	1	1
God	252	27	4	7	9	1	0	1
Goodness	1	no intro text section available	0	0	0	no intro text section available	0	0
Ground	16	no intro text section available	1	0	1	no intro text section available	0	0
Growing	5	no intro text section available	0	0	0	no intro text section available	0	0
Happiness	69	3	2	8	8	2	2	4
Hatred	123	no intro text section available	5	5	6	no intro text section available	0	0
Health	153	2	5	7	8	1	2	3
Heart	145	11	0	3	3	0	0	0
Hobby	121	2	8	0	8	1	0	1
Holiday	80	4	0	0	0	0	0	0
Home	33	5	3	1	3	1	1	2
Hospital	192	8	2	2	4	0	0	0
House	197	8	4	3	6	2	0	2
Human	871	15	20	15	33	0	8	8
Infant	139	8	6	5	7	1	1	2
Joy	81	no intro text section available	1	2	2	no intro text section available	1	1
Learning	92	14	4	2	5	2	1	2
Leisure	106	11	8	6	11	4	1	5
Light	242	17	3	2	4	0	0	0
Living	17	no intro text section available	0	0	0	no intro text section available	0	0
Love	238	5	11	11	16	2	2	4
Management	242	9	0	0	0	0	0	0
Marriage	473	23	8	9	13	3	2	4
Money	232	12	2	1	3	0	0	0
Mother	168	26	8	5	9	3	3	4
Music	254	21	3	6	9	0	0	0
Nature	323	19	10	5	11	1	0	1
Old age	87	11	6	5	7	1	0	1
Organism	229	31	4	10	11	1	6	7
Oxygen	498	51	9	11	16	1	3	4
Paper	186	10	2	4	4	0	3	3
Parent	68	6	6	4	6	4	4	6
Party	94	1	3	0	3	0	0	0
Peace	78	5	2	1	2	0	0	0
Pen	59	3	1	0	1	1	0	1
People	71	13	4	1	5	1	0	1
Pet	85	8	4	3	5	2	1	2
Philosophy	505	6	3	16	17	0	4	4
Physical fitness	34	2	2	3	4	1	0	1
Plant	420	18	12	16	19	2	3	5
Pleasure	88	5	7	4	7	1	0	1
Purpose	38	4	4	2	5	1	0	1
Rain	97	8	3	4	6	1	0	1
Religion	479	20	5	13	15	1	5	6
Sadness	125	9	6	5	6	2	0	2
School	172	17	2	3	3	2	0	2
Sea	149	13	1	1	1	0	1	1
Shoe	425	8	1	0	1	0	0	0

Sibling	92	7	6	8	9	3	0	3
Sorrow	10	no intro text section available	1	1	1	no intro text section available	1	1
Sport	127	3	1	3	4	0	0	0
Study	9	no intro text section available	0	0	0	no intro text section available	0	0
Summer	48	2	1	0	1	0	0	0
Sun	452	51	2	7	8	1	0	1
Teacher	136	7	4	3	5	0	1	1
Telephone	120	6	0	1	1	0	0	0
Television	162	14	0	10	10	0	0	0
Test (assessment)	100	19	4	0	4	1	0	1
Time	492	28	8	13	18	2	2	4
Travel	26	no intro text section available	0	1	1	no intro text section available	0	0
Tree	367	20	3	2	4	1	2	3
War	448	19	4	4	7	0	0	0
Water	523	32	10	9	15	2	2	4
Work	24	no intro text section available	0	1	1	no intro text section available	1	1
World	53	12	2	0	2	2	0	2
<i>Sum of hyperlinks unique to each observed concept</i>	20512 (14907 unique to collection of all observed concepts)	1243 (1055 unique to collection of all observed concepts)	422 (85 unique to collection of all observed concepts)	422 (88 unique to collection of all observed concepts)	652 (93 unique to collection of all observed concepts)	100 (43 unique to collection of all observed concepts)	100 (60 unique to collection of all observed concepts)	182 (70 unique to collection of all observed concepts)
<i>Average</i>	201.1 ($\approx 20512/102$)	14.0 ($\approx 1243/89$)	4.1 ($\approx 422/102$)	4.1 ($\approx 422/102$)	6.4 ($\approx 652/102$)	1.1 ($\approx 100/89$)	1.0 ($\approx 100/102$)	1.8 ($\approx 182/102$)
<i>Median value</i>	151.5	11	3.5	3	5	1	0	1

Appendix H

Comparison of number of unique start concepts and unique end concepts as well as unique start/end concepts for hyperlinks in the Wikipedia and relationships in concept maps drawn by students, especially among 102 core concepts. Values concerning the Wikipedia (in columns 2-4) are based on Appendix G considering hyperlinks departing from full text section of articles. In column 2 that shows “number of unique start/end concepts” each concept is counted only once even if occurring as both start concept and end concept. Respectively in column 5 each concept is counted only once even if occurring as both start concept and end concept and even if it is possibly mentioned by several students. In column 6 showing “number of start/end concepts (duplicates allowed)” each concept becomes counted twice if occurring both as start concept and end concept and in addition becomes counted as many times as it is mentioned by students.

Observed concept Concept	In Wikipedia			In concept maps	
	Number of unique start/end concepts of arriving/departing hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique end concepts of departing hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique start concepts of arriving hyperlinks for observed concept in Wikipedia hyperlink network among 102 core concepts	Number of unique start/end concepts in relationships for observed concept mentioned by at least two students in concept maps among 102 core concepts	Number of start/end concepts (duplicates allowed) in relationships for observed concept mentioned by at least two students in concept maps among 102 core concepts
Human	33	20	15	9	30
Plant	19	12	16	2	10
Time	18	8	13	0	0
Education	17	13	9	3	10
Philosophy	17	3	16	0	0
Love	16	11	11	12	46
Oxygen	16	9	11	1	2
Animal	15	10	10	8	27
Religion	15	5	13	1	3
Water	15	10	9	8	26
Death	14	9	7	9	42
Evolution	14	5	11	0	0
Food	14	12	5	5	17
Biology	13	9	11	1	3
Marriage	13	8	9	0	0
Family	12	6	12	24	107
Leisure	11	8	6	4	9
Nature	11	10	5	13	44
Organism	11	4	10	2	4
Adolescence	10	7	8	1	2
Child	10	9	7	4	13
Emotion	10	8	7	1	2
Television	10	0	10	3	8
Atmosphere of Earth	9	9	4	2	6
God	9	4	7	2	4
Mother	9	8	5	4	16
Music	9	3	6	1	2
Sibling	9	6	8	2 (brother)	4 (brother)
Happiness	8	2	8	3	11
Health	8	5	7	9	22
Hobby	8	8	0	5	16
Sun	8	2	7	3	7
Diet_(nutrition)	7	4	5	1	2
Eating	7	5	3	0	0
Father	7	6	5	3	15
Future	7	7	2	0	0
Infant	7	6	5	0	0
Old_age	7	6	5	2	5
Pleasure	7	7	4	0	0
War	7	4	4	1	3

Childhood	6	4	6	0	0
Clothing	6	4	3	1	2
Hatred	6	5	5	0	0
House	6	4	3	5	12
Parent	6	6	4	1	2
Rain	6	3	4	0	0
Sadness	6	6	5	0	0
Birth	5	4	1	8	31
Disease	5	1	5	2	6
Experience	5	2	3	1	2
Learning	5	4	2	1	2
People	5	4	1	0	0
Pet	5	4	3	3	7
Purpose	5	4	2	1	2
Teacher	5	4	3	1	2
Bread	4	4	1	0	0
City	4	3	1	0	0
Computer	4	2	2	3	8
Forest	4	4	2	0	0
Friendship	4	4	1	15	68
Hospital	4	2	2	1	2
Light	4	3	2	1	2
Paper	4	2	4	0	0
Physical_fitness	4	2	3	1	2
Sport	4	1	3	0	0
Test_(assessment)	4	4	0	0	0
Tree	4	3	2	3	9
Automobile	3	1	3	2	4
Bed	3	3	1	0	0
Book	3	2	2	1	2
Cat	3	3	2	1	4
Clock	3	3	2	2	4
Dog	3	3	2	4	14
Flower	3	2	2	0	0
Heart	3	0	3	1	2
Home	3	3	1	6	22
Money	3	2	1	2	8
Party	3	3	0	2	5
School	3	2	3	10	40
Dream	2	2	1	1	2
Goal	2	1	2	0	0
Joy	2	1	2	5	18
Peace	2	2	1	1	2
World	2	2	0	0	0
Ground	1	1	0	3	7
Pen	1	1	0	0	0
Sea	1	1	1	1	2
Shoe	1	1	0	1	2
Sorrow	1	1	1	3	12
Summer	1	1	0	1	2
Telephone	1	0	1	1	2
Travel	1	0	1	1	2
Work	1	0	1	12	45
Chair	0	0	0	1	2
Environment	0	0	0	3	6
Fun	0	0	0	0	0
Goodness	0	0	0	0	0
Growing	0	0	0	1	2
Holiday	0	0	0	2	4
Living	0	0	0	21	68
Management	0	0	0	0	0
Study	0	0	0	4	12
<i>Sum of start/end concepts in hyperlinks or relationships unique to each observed concept</i>	652 (93 unique to collection of all observed concepts)	422 (85 unique to collection of all observed concepts)	422 (88 unique to collection of all observed concepts)	288 (75 unique to collection of all observed concepts if word brother can represent word sister)	968 (75 unique to collection of all observed concepts if word brother can represent word sister)
<i>Average value</i>	6.392157	4.137255	4.137255	2.843137	9.584158
<i>Median value</i>	5	3.5	3	1	2

Appendix I

Connectivity between 102 core concepts in the hyperlink network of the Wikipedia based on one fixed temporal version of the Wikipedia articles that have been available online in the Wikipedia in the beginning of March 2008 (last edited versions of articles and hyperlinks by date 3 March 2008).

<i>Observed hyperlink (all hyperlinks between 102 core concepts based on hyperlinks connecting corresponding Wikipedia articles)</i>		<i>Measurable properties concerning currently observed hyperlink</i>				
Start concept in hyperlink	End concept in hyperlink	Number of occurrences of hyperlink anchor in article text of start concept (several hyperlink anchors can exist in same article text)	Number of occurrences of hyperlink anchor for a hyperlink going into opposite direction (than original hyperlink) in article text of start concept of hyperlink going into opposite direction	Sum of occurrences of hyperlink anchor for hyperlinks going into original direction and hyperlink going into opposite direction	If between 102 core concepts there is a conceptual relationship mentioned by at least two students in concept maps drawn by students that corresponds to currently observed hyperlink then how many students have mentioned this relationship in concept maps (note that direction of relationship is not specified in concept maps)	If currently observed hyperlink departs from intro text section of article text of start concept a notation "from intro text section" is mentioned in this column
Biology	Evolution	9	1	10	less than 2	from intro text section
Human	Religion	9	1	10	less than 2	
Biology	Organism	8	2	10	less than 2	
Human	Philosophy	8	0	8	less than 2	
Dog	Pet	6	3	9	3	from intro text section
Book	Paper	5	1	6	less than 2	from intro text section
Father	Mother	5	2	7	6	from intro text section
Religion	Philosophy	5	2	7	less than 2	from intro text section
Time	Clock	5	4	9	less than 2	
Animal	Plant	4	2	6	less than 2	from intro text section
Biology	Animal	4	1	5	less than 2	
Clock	Time	4	5	9	less than 2	from intro text section
Death	Disease	4	1	5	4	from intro text section
Family	Marriage	4	3	7	less than 2	from intro text section
Hatred	Pleasure	4	1	5	less than 2	
Music	Time	4	0	4	less than 2	
Nature	Animal	4	1	5	8	
Sadness	Happiness	4	0	4	less than 2	from intro text section
Sadness	Pleasure	4	1	5	less than 2	
Sibling	Parent	4	1	5	less than 2	from intro text section
Water	Human	4	0	4	less than 2	from intro text section
Water	Oxygen	4	2	6	2	
Adolescence	Child	3	1	4	less than 2	
Adolescence	Childhood	3	1	4	less than 2	from intro text section

Atmosphere_of_Earth	Oxygen	3	0	3	less than 2	from intro text section
Biology	Plant	3	1	4	less than 2	
Cat	Dog	3	1	4	4	
Child	Childhood	3	2	5	less than 2	
Education	Philosophy	3	0	3	less than 2	from intro text section
Education	School	3	2	5	3	
Emotion	Sadness	3	3	6	less than 2	
Family	Mother	3	2	5	6	
Family	Sibling	3	2	5	2	
Future	Time	3	2	5	less than 2	
Health	Diet (nutrition)	3	1	4	less than 2	
Health	Physical fitness	3	1	4	2	
Human	Animal	3	1	4	3	
Human	City	3	0	3	less than 2	
Human	Love	3	0	3	4	
Love	Pleasure	3	1	4	less than 2	
Marriage	Family	3	4	7	less than 2	from intro text section
Nature	Organism	3	0	3	less than 2	
Nature	Plant	3	1	4	5	
Parent	Mother	3	2	5	less than 2	from intro text section
Pet	Dog	3	6	9	3	from intro text section
Plant	Flower	3	1	4	less than 2	
Plant	Forest	3	1	4	less than 2	
Plant	Tree	3	0	3	5	from intro text section
Rain	Plant	3	0	3	less than 2	
Religion	God	3	1	4	less than 2	
Sadness	Emotion	3	3	6	less than 2	
Tree	Water	3	0	3	less than 2	
Water	Rain	3	1	4	less than 2	
Water	Sea	3	1	4	2	from intro text section
Animal	Organism	2	0	2	less than 2	from intro text section
Atmosphere_of_Earth	Organism	2	0	2	less than 2	from intro text section
Biology	Human	2	0	2	less than 2	
Bread	Food	2	1	3	less than 2	
Childhood	Child	2	3	5	less than 2	from intro text section
Childhood	Infant	2	1	3	less than 2	from intro text section
Death	Diet (nutrition)	2	1	3	less than 2	
Eating	Food	2	1	3	less than 2	from intro text section
Education	Adolescence	2	1	3	less than 2	
Education	Learning	2	2	4	less than 2	from intro text section
Emotion	Happiness	2	1	3	less than 2	
Emotion	Love	2	2	4	2	
Family	Father	2	1	3	7	
Father	Marriage	2	0	2	less than 2	from intro text section
Father	Parent	2	2	4	less than 2	from intro text section
Food	Animal	2	0	2	3	
Food	Plant	2	0	2	less than 2	
Food	Water	2	0	2	6	
Friendship	Love	2	2	4	8	
God	Nature	2	0	2	less than 2	
Hatred	Emotion	2	1	3	less than 2	
Hatred	Happiness	2	0	2	less than 2	
Hatred	Love	2	1	3	less than 2	
Hatred	Sadness	2	2	4	less than 2	
Health	Disease	2	0	2	2	from intro text section
Human	Adolescence	2	0	2	less than 2	
Human	Childhood	2	0	2	less than 2	
Human	Diet (nutrition)	2	0	2	less than 2	
Human	Emotion	2	0	2	less than 2	

Human	Evolution	2	0	2	less than 2	
Human	Music	2	0	2	less than 2	
Human	Old_age	2	0	2	less than 2	
Human	War	2	0	2	less than 2	
Infant	Child	2	1	3	less than 2	from intro text section
Learning	Education	2	2	4	less than 2	from intro text section
Light	Sun	2	0	2	less than 2	
Light	Time	2	1	3	less than 2	
Love	Biology	2	0	2	less than 2	
Love	Emotion	2	2	4	2	from intro text section
Love	Friendship	2	2	4	8	
Marriage	Love	2	1	3	less than 2	from intro text section
Mother	Family	2	3	5	6	
Mother	Father	2	5	7	6	from intro text section
Mother	Marriage	2	0	2	less than 2	
Mother	Parent	2	3	5	less than 2	from intro text section
Mother	Sibling	2	2	4	less than 2	
Nature	Biology	2	1	3	3	
Nature	Human	2	0	2	4	from intro text section
Nature	Oxygen	2	0	2	less than 2	
Nature	Sun	2	0	2	3	
Organism	Biology	2	8	10	less than 2	from intro text section
Oxygen	Plant	2	1	3	less than 2	from intro text section
Oxygen	Water	2	4	6	2	
Parent	Father	2	2	4	less than 2	from intro text section
Parent	Human	2	0	2	less than 2	from intro text section
Party	Television	2	0	2	less than 2	
People	Human	2	0	2	less than 2	from intro text section
People	Philosophy	2	0	2	less than 2	
Pet	Cat	2	1	3	less than 2	
Philosophy	Religion	2	5	7	less than 2	
Plant	Animal	2	4	6	less than 2	
Plant	Light	2	0	2	less than 2	
Plant	Organism	2	1	3	less than 2	from intro text section
Pleasure	Emotion	2	1	3	less than 2	
Pleasure	Happiness	2	0	2	less than 2	from intro text section
Sadness	Hatred	2	2	4	less than 2	
Sadness	Love	2	1	3	less than 2	
School	Education	2	3	5	3	from intro text section
Sibling	Family	2	3	5	2	from intro text section
Sibling	Father	2	1	3	less than 2	
Sibling	Love	2	0	2	less than 2	from intro text section
Sibling	Mother	2	2	4	less than 2	
Sun	Oxygen	2	1	3	less than 2	from intro text section
Teacher	School	2	1	3	2	
Time	Future	2	3	5	less than 2	
Tree	Forest	2	1	3	less than 2	
War	Peace	2	1	3	less than 2	
Adolescence	Education	1	2	3	less than 2	
Adolescence	Infant	1	1	2	less than 2	
Adolescence	Old_age	1	1	2	less than 2	
Adolescence	Sport	1	0	1	less than 2	
Adolescence	Television	1	0	1	less than 2	
Animal	Atmosphere_of_Earth	1	1	2	less than 2	
Animal	Biology	1	4	5	less than 2	
Animal	Evolution	1	0	1	less than 2	
Animal	Human	1	3	4	3	

Animal	Nature	1	4	5	8	
Animal	Oxygen	1	0	1	less than 2	
Animal	Time	1	0	1	less than 2	
Animal	Water	1	0	1	less than 2	
Atmosphere_of_Earth	Animal	1	1	2	less than 2	
Atmosphere_of_Earth	Automobile	1	0	1	less than 2	
Atmosphere_of_Earth	Biology	1	1	2	less than 2	
Atmosphere_of_Earth	Evolution	1	0	1	less than 2	
Atmosphere_of_Earth	Nature	1	1	2	less than 2	
Atmosphere_of_Earth	Plant	1	1	2	less than 2	
Atmosphere_of_Earth	Time	1	0	1	less than 2	
Automobile	Oxygen	1	1	2	less than 2	
Bed	Dream	1	1	2	less than 2	
Bed	Hospital	1	0	1	less than 2	
Bed	Infant	1	0	1	less than 2	
Biology	Atmosphere_of_Earth	1	1	2	less than 2	
Biology	Health	1	1	2	less than 2	
Biology	Nature	1	2	3	3	
Biology	Time	1	0	1	less than 2	
Birth	Animal	1	0	1	less than 2	from intro text section
Birth	Death	1	0	1	13	
Birth	Mother	1	0	1	less than 2	from intro text section
Birth	Sun	1	0	1	less than 2	
Book	Music	1	0	1	less than 2	
Bread	Money	1	0	1	less than 2	
Bread	Paper	1	0	1	less than 2	from intro text section
Bread	Water	1	0	1	less than 2	from intro text section
Cat	Human	1	0	1	less than 2	from intro text section
Cat	Pet	1	2	3	less than 2	
Child	Adolescence	1	3	4	less than 2	
Child	Family	1	1	2	7	
Child	Infant	1	2	3	less than 2	
Child	Leisure	1	0	1	less than 2	
Child	Marriage	1	0	1	less than 2	
Child	Old_age	1	1	2	less than 2	
Child	Parent	1	1	2	less than 2	from intro text section
Child	Sibling	1	0	1	less than 2	
Childhood	Adolescence	1	3	4	less than 2	
Childhood	Old_age	1	1	2	less than 2	
City	Automobile	1	0	1	less than 2	
City	Rain	1	0	1	less than 2	
City	Religion	1	0	1	less than 2	
Clock	Computer	1	0	1	2	
Clock	Future	1	1	2	less than 2	
Clothing	Marriage	1	0	1	less than 2	
Clothing	Paper	1	1	2	less than 2	
Clothing	Religion	1	0	1	less than 2	from intro text section
Clothing	Television	1	0	1	less than 2	
Computer	Telephone	1	0	1	less than 2	
Computer	Television	1	0	1	4	
Death	Evolution	1	0	1	less than 2	
Death	Heart	1	0	1	less than 2	
Death	Human	1	0	1	3	
Death	Organism	1	0	1	less than 2	from intro text section
Death	Oxygen	1	0	1	less than 2	
Death	Physical_fitness	1	0	1	less than 2	
Death	War	1	0	1	3	
Diet_(nutrition)	Death	1	2	3	less than 2	from intro text section

Diet_(nutrition)	Health	1	3	4	less than 2	from intro text section
Diet_(nutrition)	Organism	1	0	1	less than 2	from intro text section
Diet_(nutrition)	Religion	1	0	1	less than 2	from intro text section
Disease	Death	1	4	5	4	from intro text section
Dog	Adolescence	1	0	1	less than 2	
Dog	Cat	1	3	4	4	
Dream	Bed	1	1	2	less than 2	
Dream	God	1	0	1	less than 2	
Eating	Animal	1	0	1	less than 2	from intro text section
Eating	Human	1	0	1	less than 2	from intro text section
Eating	Organism	1	0	1	less than 2	from intro text section
Eating	Plant	1	0	1	less than 2	from intro text section
Education	Biology	1	0	1	less than 2	
Education	Child	1	0	1	less than 2	
Education	Childhood	1	0	1	less than 2	
Education	Family	1	0	1	less than 2	
Education	Human	1	0	1	less than 2	
Education	Leisure	1	1	2	less than 2	
Education	Marriage	1	0	1	less than 2	
Education	Sibling	1	0	1	less than 2	
Education	Teacher	1	1	2	less than 2	
Emotion	Evolution	1	0	1	less than 2	from intro text section
Emotion	Experience	1	0	1	less than 2	from intro text section
Emotion	Hatred	1	2	3	less than 2	
Emotion	Joy	1	0	1	less than 2	
Emotion	Pleasure	1	2	3	less than 2	
Evolution	Biology	1	9	10	less than 2	from intro text section
Evolution	Organism	1	1	2	less than 2	
Evolution	Oxygen	1	0	1	less than 2	
Evolution	Philosophy	1	0	1	less than 2	
Evolution	Plant	1	0	1	less than 2	
Experience	Philosophy	1	0	1	less than 2	
Experience	Time	1	0	1	less than 2	
Family	Child	1	1	2	7	
Family	Leisure	1	1	2	less than 2	
Father	Family	1	2	3	7	
Father	Love	1	0	1	less than 2	
Father	Sibling	1	2	3	less than 2	
Flower	Evolution	1	0	1	less than 2	
Flower	Plant	1	3	4	less than 2	
Food	Bread	1	2	3	less than 2	
Food	Computer	1	0	1	less than 2	
Food	Death	1	0	1	less than 2	
Food	Diet_(nutrition)	1	0	1	less than 2	
Food	Eating	1	2	3	less than 2	from intro text section
Food	Health	1	1	2	3	
Food	Human	1	0	1	less than 2	
Food	School	1	0	1	less than 2	
Food	War	1	0	1	less than 2	
Forest	Flower	1	0	1	less than 2	
Forest	Plant	1	3	4	less than 2	
Forest	Rain	1	0	1	less than 2	
Forest	Tree	1	2	3	less than 2	from intro text section
Friendship	Adolescence	1	0	1	2	
Friendship	Animal	1	0	1	less than 2	
Friendship	Philosophy	1	0	1	less than 2	from intro text section
Future	Clock	1	1	2	less than 2	
Future	Death	1	0	1	less than 2	
Future	Evolution	1	0	1	less than 2	
Future	Human	1	0	1	less than 2	
Future	Philosophy	1	0	1	less than 2	

Future	Religion	1	0	1	less than 2	
Goal	Purpose	1	1	2	less than 2	
God	Father	1	0	1	less than 2	
God	Philosophy	1	1	2	less than 2	
God	Religion	1	3	4	less than 2	from intro text section
Ground	Philosophy	1	0	1	less than 2	
Happiness	Emotion	1	2	3	less than 2	from intro text section
Happiness	Joy	1	1	2	less than 2	from intro text section
Health	Biology	1	1	2	less than 2	
Health	Food	1	1	2	3	
Hobby	Book	1	0	1	less than 2	
Hobby	Eating	1	0	1	less than 2	
Hobby	Education	1	0	1	less than 2	
Hobby	Food	1	0	1	less than 2	
Hobby	House	1	0	1	less than 2	
Hobby	Leisure	1	0	1	3	from intro text section
Hobby	Plant	1	0	1	less than 2	
Hobby	Sport	1	0	1	less than 2	
Home	Family	1	0	1	9	from intro text section
Home	House	1	1	2	3	
Home	Love	1	0	1	less than 2	
Hospital	Disease	1	0	1	less than 2	
Hospital	Health	1	0	1	less than 2	
House	Family	1	0	1	3	from intro text section
House	Home	1	1	2	3	from intro text section
House	Pet	1	0	1	less than 2	
House	Television	1	0	1	less than 2	
Human	Clothing	1	0	1	less than 2	
Human	Family	1	0	1	4	
Human	God	1	0	1	less than 2	
Human	Happiness	1	0	1	less than 2	
Human	Health	1	0	1	less than 2	
Human	House	1	0	1	less than 2	
Human	Oxygen	1	0	1	less than 2	
Infant	Adolescence	1	1	2	less than 2	
Infant	Childhood	1	2	3	less than 2	
Infant	Health	1	0	1	less than 2	
Infant	Hospital	1	0	1	less than 2	
Infant	Old_age	1	1	2	less than 2	
Joy	Happiness	1	1	2	less than 2	
Learning	Experience	1	0	1	less than 2	from intro text section
Learning	Physical fitness	1	0	1	less than 2	
Learning	Time	1	0	1	less than 2	
Leisure	Eating	1	0	1	less than 2	from intro text section
Leisure	Education	1	1	2	less than 2	from intro text section
Leisure	Family	1	1	2	less than 2	
Leisure	Marriage	1	1	2	less than 2	
Leisure	Sibling	1	0	1	less than 2	
Leisure	Television	1	0	1	2	
Leisure	Time	1	0	1	less than 2	from intro text section
Leisure	Work	1	0	1	less than 2	from intro text section
Light	Television	1	0	1	less than 2	
Love	Family	1	0	1	13	from intro text section
Love	Happiness	1	0	1	3	
Love	Hatred	1	2	3	less than 2	
Love	Marriage	1	2	3	less than 2	
Love	Philosophy	1	0	1	less than 2	
Love	Religion	1	0	1	less than 2	
Love	Sadness	1	2	3	less than 2	
Marriage	Death	1	0	1	less than 2	
Marriage	Emotion	1	0	1	less than 2	
Marriage	God	1	0	1	less than 2	

Marriage	Leisure	1	1	2	less than 2	
Marriage	Religion	1	0	1	less than 2	from intro text section
Marriage	Sibling	1	1	2	less than 2	
Money	Food	1	0	1	less than 2	
Money	Water	1	0	1	less than 2	
Mother	Human	1	0	1	less than 2	from intro text section
Mother	Leisure	1	0	1	less than 2	
Mother	Love	1	0	1	2	
Music	Religion	1	0	1	less than 2	
Music	Television	1	0	1	less than 2	
Nature	Atmosphere_of_Earth	1	1	2	less than 2	
Nature	Evolution	1	0	1	less than 2	
Nature	Time	1	0	1	less than 2	
Old_age	Adolescence	1	1	2	less than 2	
Old_age	Biology	1	0	1	less than 2	from intro text section
Old_age	Child	1	1	2	less than 2	
Old_age	Childhood	1	1	2	less than 2	
Old_age	Death	1	0	1	3	
Old_age	Infant	1	1	2	less than 2	
Organism	Evolution	1	1	2	less than 2	
Organism	Heart	1	0	1	less than 2	
Organism	Plant	1	2	3	less than 2	
Oxygen	Automobile	1	1	2	less than 2	
Oxygen	Disease	1	0	1	less than 2	
Oxygen	Heart	1	0	1	less than 2	
Oxygen	Philosophy	1	0	1	less than 2	
Oxygen	Rain	1	0	1	less than 2	
Oxygen	Sport	1	0	1	less than 2	
Oxygen	Sun	1	2	3	less than 2	
Paper	Book	1	5	6	less than 2	
Paper	Clothing	1	1	2	less than 2	
Parent	Birth	1	0	1	less than 2	from intro text section
Parent	Child	1	1	2	less than 2	
Parent	Sibling	1	4	5	less than 2	
Party	Family	1	0	1	less than 2	
Party	Music	1	0	1	less than 2	
Peace	Education	1	0	1	less than 2	
Peace	War	1	2	3	less than 2	
Pen	Paper	1	0	1	less than 2	from intro text section
People	Purpose	1	0	1	less than 2	
People	Religion	1	0	1	less than 2	
Pet	Animal	1	0	1	less than 2	from intro text section
Pet	People	1	0	1	less than 2	
Philosophy	God	1	1	2	less than 2	
Philosophy	Music	1	0	1	less than 2	
Physical_fitness	Diet_(nutrition)	1	0	1	less than 2	
Physical_fitness	Health	1	3	4	2	from intro text section
Plant	Atmosphere_of_Earth	1	1	2	less than 2	
Plant	Biology	1	3	4	less than 2	
Plant	Nature	1	3	4	5	
Plant	Oxygen	1	2	3	less than 2	
Plant	Time	1	0	1	less than 2	
Plant	Water	1	1	2	less than 2	
Pleasure	Hatred	1	4	5	less than 2	
Pleasure	Love	1	3	4	less than 2	
Pleasure	Music	1	0	1	less than 2	
Pleasure	Philosophy	1	0	1	less than 2	
Pleasure	Sadness	1	4	5	less than 2	
Purpose	Goal	1	1	2	less than 2	from intro text section
Purpose	God	1	0	1	less than 2	
Purpose	Happiness	1	0	1	less than 2	
Purpose	Philosophy	1	0	1	less than 2	
Rain	Sun	1	0	1	less than 2	
Rain	Water	1	3	4	less than 2	from intro text section

Religion	Evolution	1	0	1	less than 2	
Religion	Human	1	9	10	less than 2	
Religion	Sun	1	0	1	less than 2	
Sadness	Sorrow	1	1	2	less than 2	from intro text section
School	Teacher	1	2	3	2	from intro text section
Sea	Water	1	3	4	2	
Shoe	Clothing	1	0	1	2	
Sibling	Marriage	1	1	2	less than 2	
Sorrow	Sadness	1	1	2	less than 2	
Sport	Television	1	0	1	less than 2	
Summer	Plant	1	0	1	less than 2	
Sun	Plant	1	0	1	less than 2	
Teacher	Education	1	1	2	less than 2	
Teacher	Goal	1	0	1	less than 2	
Teacher	Learning	1	0	1	less than 2	
Test_(assessment)	Education	1	0	1	less than 2	from intro text section
Test_(assessment)	Music	1	0	1	less than 2	
Test_(assessment)	Philosophy	1	0	1	less than 2	
Test_(assessment)	Teacher	1	0	1	less than 2	
Time	Education	1	0	1	less than 2	
Time	God	1	0	1	less than 2	
Time	Light	1	2	3	less than 2	
Time	Philosophy	1	0	1	less than 2	from intro text section
Time	Religion	1	0	1	less than 2	from intro text section
Time	Television	1	0	1	less than 2	
Tree	Oxygen	1	0	1	less than 2	from intro text section
War	Disease	1	0	1	less than 2	
War	Hatred	1	0	1	less than 2	
War	Religion	1	0	1	less than 2	
Water	Biology	1	0	1	less than 2	
Water	Organism	1	0	1	less than 2	
Water	Plant	1	1	2	less than 2	
Water	Sun	1	0	1	less than 2	
Water	Time	1	0	1	less than 2	
Water	Travel	1	0	1	less than 2	
World	Experience	1	0	1	less than 2	from intro text section
World	Human	1	0	1	less than 2	from intro text section

Appendix J

Listing of all 212 hyperlinks belonging to “hyperlink network of 55 concepts” that was used in exploration experiment with students (n=49). All these 212 hyperlinks are connecting concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (containing 55 concepts including concept Human). All these 212 hyperlinks are shown here supplied with a relation statement for each hyperlink in English and its Finnish translation. In relation statement the start concept has been indicated with a notation starting with character string “A1” and ending with character string “A2” and the end concept has been indicated with a notation starting with character string “B1” and ending with character string “B2”. These notations helped to automatically highlight with different colors both start concept and end concept in relation statement when it was shown to the student during exploration experiment.

Relation statements have been extracted from the article of start concept, primarily taken around hyperlink pointing to end concept, but possibly with some modifications. Please note that due to lack of suitable sentence surrounding hyperlink anchor of start concept of hyperlink some of the relation statements are generated and synthesized based on other contextual text segments we identified relatively near the hyperlink anchor or possibly based on relation statement we managed to identify for another hyperlink going into opposite direction (i.e. for a hyperlink whose start concept is end concept of current hyperlink and end concept is start concept of current hyperlink). In column 3 relation statement is supplied with notation “(taken from other part of article)” if this relation statement has been generated and synthesized with this special method but this additional notation was not shown to the student.

Hyperlink		Relation statement (extracted from the article of start concept, primarily taken around hyperlink pointing to end concept, but possibly with some modifications)	
<i>Start concept in hyperlink</i>	<i>End concept in hyperlink</i>	<i>Relation statement in English (original language version)</i>	<i>Relation statement translated to Finnish</i>
Adolescence	Child	in A1adolescenceA2 B1childB2 develops sex characteristics	A1nuoruudessaA2 B1lapselleB2 kehittyä sukupuoliominaisuuksia
Adolescence	Education	in A1adolescenceA2 B1educationB2 of children changes from elementary school to secondary school (taken from other part of article)	A1nuoruudessaA2 lasten B1koulutusB2 siirtyä alakoulusta yläkouluun
Adolescence	Old_age	B1old ageB2 is a matured stage of personal development which contains also A1adolescenceA2 (taken from other part of article)	B1vanhuusB2 on kypsyntä vaihe yksilönkehityksessä johon myös A1nuoruusA2 kuuluu
Adolescence	Television	B1televisionB2 programs are popular amongst A1adolescentsA2	B1televisioB2-ohjelmat ovat suosittuja A1nuortenA2 keskuudessa
Animal	Biology	in nature B1biologyB2 has a central role for life such as A1animalsA2 (taken from other part of article)	luonnossa B1biologiallaB2 on keskeinen merkitys elämälle, kuten A1eläimilleA2
Animal	Human	when talking about A1animalsA2 it is often referred to other animals than B1humansB2	A1eläimistäA2 puhuttaessa usein viitataan muihin eläimiin kuin B1ihmisiinB2
Animal	Nature	B1natureB2 has a central role for A1animalsA2 (taken from other part of article)	B1luonnollaB2 on keskeinen merkitys A1eläimilleA2
Animal	Organism	A1animalsA2 are multicellular B1organismsB2	A1eläimetA2 ovat monisoluisia B1eliöitäB2
Animal	Oxygen	A1animalsA2 benefit from process in which the energy of sunlight helps to release B1oxygenB2 (taken from other part of article)	A1eläimetA2 hyötyvät siitä että auringonvalon energian avulla vapautuu B1happeaB2
Animal	Plant	A1animalsA2 generally digest food internally which separates them from B1plantsB2 (taken	A1eläimetA2 yleensä sulattavat ravinnon sisäisesti mikä erottaa ne

		from other part of article)	B1kasveistaB2
Animal	Water	A1animalsA2 benefit from plants which with carbon dioxide and B1waterB2 store the energy of sunlight (taken from other part of article)	A1eläimetA2 hyötyvät kasveista jotka hiilidioksidin ja B1vedenB2 avulla varastoivat auringonvalon energiaa
Automobile	Oxygen	Francois Rivaz designed the first A1automobileA2 that was fuelled by hydrogen and B1oxygenB2	Francois Rivaz suunnitteli ensimmäisen vetyä ja B1happeaB2 polttoaineena käyttäneen A1autonA2
Biology	Animal	zoology that belongs to A1biologyA2 involves the study of B1animalsB2 (taken from other part of article)	A1biologianA2 osana oleva eläintiede on B1eläimiinB2 kohdistuvaa tutkimusta
Biology	Health	A1biologyA2 is considered as a general effective factor to B1healthB2 (taken from other part of article)	A1biologiaA2 pidetään yleisenä vaikuttavana tekijänä B1terveyteenB2
Biology	Human	cell biology that belongs to A1biologyA2 researches multicellular organisms like B1humansB2	A1biologianA2 osana oleva solubiologia tutkii monisoluisia eliöitä, kuten B1ihmisiäB2
Biology	Nature	B1natureB2 has a central role for A1biologyA2 (taken from other part of article)	B1luonnollaB2 on keskeinen merkitys A1biologiassaA2
Biology	Organism	based on A1biologyA2 all B1organismsB2 descend from a common ancestor or gene pool (taken from other part of article)	A1biologianA2 perusteella kaikki B1eliötB2 periytyvät yhteisistä esivanhemmista tai geenijoukosta
Biology	Plant	botany that belongs to A1biologyA2 is the scientific study of B1plantsB2 (taken from other part of article)	A1biologianA2 osana oleva kasvitiede on B1kasvienB2 tieteellistä tutkimista
Birth	Animal	in A1birthA2 an offspring of an B1animalB2 is expelled from the body of its mother	A1syntymässäA2 B1eläimenB2 jälkeläinen poistuu äidin kehosta
Birth	Death	there are beliefs about a new A1birthA2 after B1deathB2 (taken from other part of article)	on uskomuksia uudelleen A1syntymisestäA2 B1kuolemanB2 jälkeen
Birth	Mother	in A1birthA2 an offspring of an animal is expelled from the body of its B1motherB2	A1syntymässäA2 eläimen jälkeläinen poistuu B1äidinB2 kehosta
Birth	Sun	there are beliefs that an individual's life is influenced by the positions of the B1SunB2 in the sky at the moment of A1birthA2	on uskomuksia että elämään vaikuttaa B1auringonB2 sijainti taivaalla A1syntymänA2 hetkellä
Cat	Dog	A1catsA2 do not hunt in groups as B1dogsB2 do	A1kissatA2 eivät saalista ryhmissä, kuten B1koiratB2
Cat	Human	A1catA2 is a crepuscular mammal that is often valued by B1humansB2	A1kissaA2 on hämärässä liikkuva nisäkäs, josta B1ihmisetB2 usein pitävät
Cat	Pet	some people keep A1catsA2 as B1petsB2	jotkut pitävät A1kissojaA2 B1lemmikkieläiminäB2
Child	Adolescence	B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2	B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu
Child	Family	according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life (taken from other part of article)	myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Child	Leisure	according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Child	Old_age	B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2 (taken from other part of article)	B1vanhuusB2 on kypsytynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu
Child	Parent	A1childA2 as a term may define a relationship with a B1parentB2 or authority (taken from other part of article)	A1lapsiaA2 käsitteenä voi määrittellä suhteen B1vanhempaanB2 tai auktoriteettiin
Child	Sibling	according to the declaration of	myös A1lapsiaA2 koskevan

		human rights that covers also A1 children A2 everyone has right for B1 brotherhood B2 (taken from other part of article)	ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1 sisarus B2 suhteisiin
Clothing	Religion	A1 clothing A2 is worn to reflect meaning of B1 religion B2 (taken from other part of article)	A1 vaatetusta A2 käytetään heijastamaan B1 uskonnon B2 merkityksiä
Clothing	Television	in A1 clothing A2 costume history serves as a topic of professional interest to costumers constructing for B1 television B2 (taken from other part of article)	A1 vaatetuksessa A2 pukujen historia on ammatillisesti kiinnostava puvustajille B1 televisiossa B2
Computer	Telephone	personal A1 computers A2 are becoming as common as the B1 telephone B2	henkilökohtaiset A1 tietokoneet A2 ovat tulossa yhtä yleiseksi kuin B1 puhelin B2
Computer	Television	personal A1 computers A2 are becoming as common as the B1 television B2	henkilökohtaiset A1 tietokoneet A2 ovat tulossa yhtä yleiseksi kuin B1 televisio B2
Death	Diet_(nutrition)	causes of A1 death A2 can be postponed by B1 diet B2	syitä A1 kuolemaan A2 voidaan lykätä B1 ravinnolla B2
Death	Disease	many factors can contribute to an organism's A1 death A2, including B1 disease B2	eliön A1 kuolemaan A2 voivat vaikuttaa useat tekijät mukaan lukien B1 sairaudet B2
Death	Heart	A1 death A2 was once defined as the cessation of beating of B1 heart B2	aikoinaan A1 kuolema A2 määriteltiin B1 sydämen B2 löyntiin pysähtymisenä
Death	Human	an autopsy is examination of a B1 human B2 corpse to determine the cause of a person's A1 death A2	ruumiinavaus on B1 ihmisen B2 ruumiin tutkiminen A1 kuoleman A2 syyn selvittämiseksi
Death	Organism	A1 death A2 is the end of the life of a biological B1 organism B2	A1 kuolema A2 on biologisen B1 eliön B2 elämän päättyminen
Death	Oxygen	a loss of homeostasis of body related to A1 death A2 causes loss of B1 oxygen B2	A1 kuolemaan A2 liittyvä elimistön tasapainon menetys aiheuttaa B1 hapen B2 puutetta
Death	War	B1 war B2 can be considered as a situation whereby A1 death A2 assumes absolute value (taken from article War)	B1 sotaa B2 voidaan pitää tilanteena, jossa A1 kuolema A2 saa ehdottoman aseman
Diet_(nutrition)	Death	A1 dietary A2 habits and choices play a significant role in prevalence TARKISTA of B1 death B2	A1 ravintoon A2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1 kuoleman B2 esiintyvyyteen
Diet_(nutrition)	Health	A1 dietary A2 habits and choices play a significant role in B1 health B2	A1 ravintoon A2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1 terveyteen B2
Diet_(nutrition)	Organism	the A1 diet A2 is the sum of food consumed by an B1 organism B2	A1 ravinto A2 on kokonaisuus ruoasta, jonka B1 eliö B2 nauttii
Diet_(nutrition)	Religion	A1 dietary A2 habits and choices play a significant role in B1 religion B2	A1 ravintoon A2 liittyvillä tavoilla ja valinnoilla on suuri merkitys B1 uskonnolle B2
Disease	Death	A1 disease A2 is often used to refer to a uncomfortable condition possibly leading to B1 death B2	A1 sairaudella A2 viitataan usein epämiellyttävään mahdollisesti B1 kuolemaan B2 johtavaan olotilaan
Dog	Adolescence	B1 adolescence B2 for most domestic A1 dogs A2 is around age of 12 to 15 months	B1 nuoruus B2 vaihe useimmille kesy A1 koirille A2 on 12-15 kuukauden iässä
Dog	Cat	unlike the B1 cat B2 the A1 dog A2 is not dependent on meat based protein in diet	toisin kuin B1 kissa B2 A1 koira A2 ei ole riippuvainen lihaperäisestä proteiinista ravinnossa
Dog	Pet	the domestic A1 dog A2 has been one of the most widely-kept working animals and B1 pets B2 in human history	kesy A1 koira A2 on ollut eräs yleisimpiä työ- ja B1 lemmikkieläimiä B2 ihmisen historiassa
Education	Adolescence	A1 education A2 in secondary school occurs during B1 adolescence B2	yläluokilla tarjottava A1 koulutus A2 tapahtuu B1 nuoruuden B2 aikana

Education	Biology	educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2 (taken from other part of article)	A1koulutustaA2 koskeva kasvatuspsykologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2
Education	Child	A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are	A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat
Education	Family	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Education	Human	A1educationA2 is a means to foster future development of B1humansB2	A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittymistä
Education	Learning	A1educationA2 encompasses teaching and B1learningB2 specific skills	A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2
Education	Leisure	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Education	School	progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate (taken from other part of article)	A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa
Education	Sibling	according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2 (taken from other part of article)	myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin
Education	Teacher	in A1educationA2 informal relationships can be established between B1teachersB2 and students (taken from other part of article)	A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä
Emotion	Experience	different A1emotionsA2 are associated with relatively distinct subjective B1experienceB2	erilaisia A1tunteitaA2 liittyy suhteellisen erillisiin omakohtaisiin B1kokemuksiinB2
Emotion	Happiness	list of basic A1emotionsA2 devised by Paul Ekman contains B1happinessB2 (taken from other part of article)	Paul Ekmanin ehdottama luettelo perusA1tunteistaA2 sisältää B1onnellisuudenB2
Emotion	Joy	according to Rober Plutchik B1joyB2 belongs to eight primary A1emotionsA2 (taken from other part of article)	Robert Plutchikin mukaan kahdeksaan ensisijaiseen A1tunteeseenA2 kuuluu B1iloB2
Emotion	Love	human A1emotionA2 of B1loveB2 is proposed to have evolved from the care of offspring	ihmisen B1rakkautenB2 A1tunteenA2 on ehdotettu kehittyneen jälkeläisistä huolehtimisesta
Family	Child	A1familyA2 serves to give social orientation for B1childrenB2 (taken from other part of article)	A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti
Family	Father	concerning A1familyA2 a B1fatherB2 is a male parent (taken from other part of article)	A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi
Family	Leisure	according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2
Family	Mother	concerning A1familyA2 a B1motherB2 is a female parent (taken from other part of article)	A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi
Family	Sibling	in A1familyA2 a B1siblingB2 is a child of the same parents (taken from other part of article)	A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat
Father	Family	like B1familyB2 also role of A1fatherA2 can be considered to implement ruling (taken from other part of article)	kuten B1perhettäB2, myös A1isänA2 roolia voidaan pitää hallinnan ilmentäjinä

Father	Love	B1loveB2 belongs to relationships concerning A1fatherA2 (taken from other part of article)	A1isääA2 koskeviin ihmissuhteisiin kuuluu B1rakkausB2
Father	Mother	previously social rules determined who would be regarded as a A1fatherA2 i.e. the husband of the B1motherB2	ennen sosiaaliset säännöt määräisivät kenet katsottiin A1isäksiA2 eli B1äidinB2 mieheksi
Father	Parent	A1fatherA2 is a male B1parentB2 of an offspring	A1isääA2 on jälkeläisen miespuolinen B1vanhempiB2
Father	Sibling	concerning A1fatherA2 the B1siblingsB2 belong to the closest members of family (taken from other part of article)	A1isäänA2 liittyviin lähimpiin perheenjäseniin kuuluvat B1sisaruksetB2
Food	Animal	meat is an example of A1foodA2 directly coming from an B1animalB2 (taken from other part of article)	liha on esimerkki A1ruoastaA2 joka saadaan suoraan B1eläimestäB2
Food	Computer	control systems based on B1computersB2 can improve safety of A1foodA2	B1tietokoneisiinB2 perustuvat valvontajärjestelmät voivat parantaa A1ruoanA2 turvallisuutta
Food	Death	habits of consuming A1foodA2 play a significant role in the prevalence of B1deathB2	A1ruoanA2 käyttötottumuksilla on huomattava merkitys B1kuolemanB2 esiintymiseen
Food	Diet_(nutrition)	in A1foodA2 inorganic substances, like water, are important part of human B1dietB2 (taken from other part of article)	A1ruoassaA2 epäorgaaniset aineet, kuten vesi, ovat tärkeä osa ihmisen B1ravintoaB2
Food	Health	habits of consuming A1foodA2 play a significant role in the B1healthB2	A1ruoanA2 käyttötottumuksilla on huomattava merkitys B1terveyteenB2
Food	Human	the listing of A1foodA2stuffs include any substance ingested by B1humansB2	luettelo A1ruokaA2-aineista sisältää kaikenlaisia aineita, joita B1ihmisetB2 nauttivat ravinnoksi
Food	Plant	Many B1plantsB2 or their parts are eaten as A1foodA2.	useita B1kasvejaB2 tai niiden osia syödään A1ruokanaA2
Food	School	concerning A1foodA2 in out-of-home dining 6.6% of expenditures were based on B1schoolsB2 (taken from other part of article)	kodin ulkopuolisessa A1ruoanA2 nauttimisessa 6,6 prosenttia kuluista tapahtuu B1kouluissaB2
Food	War	production of A1foodA2 is influenced by international organizations and B1warB2	A1ruoanA2 tuotantoon vaikuttavat kansainväliset järjestöt ja B1sodanB2käynti
Food	Water	in A1foodA2 inorganic substances, like B1waterB2, are important part of human diet (taken from other part of article)	A1ruoassaA2 epäorgaaniset aineet, kuten B1vesiB2, ovat tärkeä osa ihmisen ravintoa
Friendship	Adolescence	A1friendshipsA2 are often the most important human relationships of the emotional life in B1adolescenceB2 (taken from other part of article)	A1ystävyyttäA2suhteet ovat usein tärkeimpiä tunne-elämän ihmissuhteita B1nuoruudessaB2
Friendship	Animal	in interpersonal relationships A1friendshipsA2 are found also among B1animalsB2 with high intelligence (taken from other part of article)	yksilöiden välisissä suhteissa A1ystävyyttäA2 esiintyy myös älykkäillä B1eläimilläB2
Friendship	Love	concerning A1friendshipA2 B1loveB2 is above all other motives as an inspiration (taken from other part of article)	A1ystävyyteenA2 liittyen B1rakkausB2 on kaikkien muiden motiivien yläpuolella innoittaja
God	Father	interpretation of A1godA2 as a B1fatherB2 is common in monotheistic Western culture (taken from other part of article)	yksijumalisessa länsimaisessa kulttuurissa tulkinta A1jumalastaA2 B1isäB2hahmona on yleinen
God	Nature	concerning B1natureB2 questions about the	B1luontoaB2 koskien kysymykset A1jumalanA2

		characteristics of A1godA2 are non-empirical and are domain of theology (taken from other part of article)	olemuksesta ovat ei-empiirisiä ja kuuluvat teologiaan
God	Religion	a A1godA2 most commonly refers to the deity worshiped by B1religionsB2	A1jumalaA2 useimmin viittaa ylluonnolliseen hahmoon, jota palvotaan B1uskonnoissaB2
Happiness	Emotion	A1happinessA2 is B1emotionB2 covering experiences ranging from satisfaction to joy (taken from other part of article)	A1onnellisuusA2 on B1tunneB2tila kattaen kokemuksia tyytyväisyydestä iloon
Happiness	Joy	A1happinessA2 is emotion covering experiences ranging from satisfaction to B1joyB2	A1onnellisuusA2 on tunnetila kattaen kokemuksia tyytyväisyydestä B1iloonB2
Health	Biology	A1healthA2 research builds primarily on the basic sciences like B1biologyB2 (taken from other part of article)	A1terveyttäA2 koskeva tutkimus rakentuu pääasiallisesti perustieteisiin, kuten B1biologiaanB2
Health	Diet_(nutrition)	bodily A1healthA2 is the result of e.g. regular proper B1dietB2	elimistön A1terveysA2 on seurausta mm. kunnollisesta B1ravinnostaB2
Health	Disease	A1healthA2 is a state of complete well-being and not merely the absence of B1diseaseB2	A1terveysA2 on kokonaisvaltaista hyvinvointia, eikä pelkästään B1sairaudenB2 puutetta
Health	Food	concerning A1healthA2 food pyramid is a general nutrition guide for B1foodB2 consumption (taken from other part of article)	A1terveyttäA2 koskeva ruokapyramidi on yleinen ravitsemusopas B1ruoanB2 kulutukselle
Home	Family	A1homeA2 is a place where a B1familyB2 lives together	A1kotiA2 on paikka, missä B1perheB2 asuu yhdessä
Home	House	B1houseB2 or residential dwelling is often referred to as a A1homeA2	B1talonB2 tai asuntoon viitataan usein A1kotinaA2
Home	Love	A1homeA2 is a place where people that one B1lovesB2 becomes the focus (taken from other part of article)	A1kotiA2 on paikka, missä B1rakkaudenB2 kohteena olevat ihmiset saavat huomiota
House	Family	concerning A1houseA2 a household is most commonly a B1familyB2 unit of some kind	A1talonA2 liittyen kotitalous on useimmin jonkinlainen B1perheB2yksikkö
House	Home	concerning A1houseA2 people generally call any building they routinely occupy B1homeB2	A1talonA2 liittyen ihmiset kutsuvat usein pysyvää asuinpaikkaansa B1kodiksiB2
House	Pet	human interest in building A1housesA2 for animals does not stop at the domestic B1petB2	ihmisten kiinnostus rakentaa A1talojaA2 eläimille ei rajoitu vain B1lemmikkieläimiinB2
House	Television	parts of A1houseA2 often include B1televisionB2 room (taken from other part of article)	A1talonA2 osiin tyypillisesti kuuluu B1televisiollaB2 varustettu huone
Human	Adolescence	A1humanA2 life span can be split into a number of stages like B1adolescenceB2	A1ihmisenA2 elämänskaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2
Human	Animal	advent of agriculture by A1humansA2 led to domestication of B1animalsB2 (taken from other part of article)	A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesyttämiseen
Human	Clothing	A1humansA2 are the only species known to B1clotheB2 themselves	A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2
Human	Diet_(nutrition)	concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2	A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristötekijät, kuten B1ravintoB2
Human	Emotion	concerning A1humansA2 motivation is connected to B1emotionsB2 (taken from other part of article)	A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2
Human	Family	A1humansA2 create complex	A1ihmisetA2 muodostavat

		social structures such as B1familiesB2	monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2
Human	God	concerning A1humanA2 religions a common source for answers to questions are beliefs in B1godB2 (taken from other part of article)	A1ihmistenA2 harjoittamissa uskonnoissa vastauksia kysymyksiin saadaan uskonnuksesta B1jumalaanB2
Human	Happiness	B1happinessB2 is a A1humanA2 emotional condition	B1onnellisuusB2 on A1ihmisenA2 tunnetila
Human	Health	the best condition for A1humanA2 can be considered mental and physical B1healthB2 (taken from other part of article)	A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2
Human	House	concerning A1humansA2 habitat and population influence characteristics of B1housesB2 (taken from other part of article)	A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen
Human	Love	concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2 (taken from other part of article)	A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2
Human	Music	concerning A1humansA2 art is connected to B1musicB2 (taken from other part of article)	A1ihmisenA2 harjoittamaan taiteeseen liittyy B1musiikkiB2
Human	Old_age	A1humanA2 life span can be split into a number of stages like B1old ageB2	A1ihmisenA2 elämänskaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2
Human	Oxygen	A1humanA2 body contains 25.5 percent B1oxygenB2 (taken from other part of article)	A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia
Human	Religion	A1humansA2 are noted for their desire seeking explanations through B1religionB2	A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta
Human	War	B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources (taken from other part of article)	A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2
Joy	Happiness	A1joyA2 is an emotion of great B1happinessB2	A1iloA2 on tunne suuresta B1onnellisuudestaB2
Learning	Education	A1learningA2 is the goal of B1educationB2 (taken from other part of article)	A1oppiminenA2 on B1koulutuksenB2 tavoite
Learning	Experience	A1learningA2 is the product of B1experienceB2 (taken from other part of article)	A1oppiminenA2 on seurausta B1kokemuksestaB2
Leisure	Education	A1leisureA2 is the period of discretionary time outside compulsory activities such as B1educationB2 (taken from other part of article)	A1vapaa-aikaaA2 on omaehtoinen ajanjakso pakollisten tehtävien, kuten B1koulutuksenB2, ulkopuolella
Leisure	Family	according to the declaration of human rights that covers also A1leisureA2 everyone has right for B1familyB2 life	myös A1vapaa-aikaaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus oikeus B1perheB2-elämään
Leisure	Sibling	according to the declaration of human rights that covers also A1leisureA2 everyone has right for B1brotherhoodB2 (taken from other part of article)	myös A1vapaa-aikaaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin
Leisure	Television	passive A1leisureA2 activities are those in which a person does not exert any significant physical or mental energy, such as watching B1televisionB2	passiivisissa A1vapaa-ajanA2 tehtävissä, kuten B1televisionB2 katselussa, ei käytetä merkittävästi voimia
Leisure	Work	A1leisureA2 is a period of time spent out of B1workB2	A1vapaa-aikaaA2 on ajanjakso, joka käytetään ilman B1työtäB2
Light	Sun	examples of A1lightA2 source include the radiation emitted by the chromosphere of the B1SunB2 (taken from other part of article)	esimerkki A1valonA2lähteestä on B1aurionB2 koromofääristä lähtevä säteily
Light	Television	phenomena of phosphorescence	katodisädeputkeen

		is is used in cathode ray tube B1televisionsB2 for producing A1lightA2 (taken from other part of article)	perustuvissa B1televisioissaB2 käytetään fosforensi-ilmiötä A1valonA2 synnyttämisessä
Love	Biology	according to B1biologyB2 there are two major drives in A1loveA2: sexual attraction and attachment	B1biologianB2 perusteella A1rakkaudelleA2 on kaksi vaikutinta: seksuaalinen vetovoima ja kiintymys
Love	Emotion	A1loveA2 can describe an intense feeling of affection, an B1emotionB2 or an emotional state (taken from other part of article)	A1rakkausA2 voi tarkoittaa kiihkeää kiintymystä, B1tunnettaB2 tai tunnetilaa
Love	Family	A1loveA2 has many different meanings ranging to something one would die for, like B1familyB2 (taken from other part of article)	A1rakkaudellaA2 on eri merkityksiä ulottuen johonkin, jonka puolesta kuolla, kuten B1perheB2
Love	Friendship	concerning A1loveA2 B1friendshipB2 means the spirit between friends (taken from other part of article)	A1rakkauteenA2 liittyen B1ystävyydenB2 merkitsee ystävien välillä vallitsevaa yhteishenkeä
Love	Happiness	A1loveA2 is connected to emotions about B1happinessB2 (taken from other part of article)	A1rakkauteenA2 liittyy tunteita B1onnellisuudestaB2
Love	Religion	throughout history, philosophy and B1religionB2 have done the most speculation on the phenomenon of A1loveA2	läpi historian filosofia ja B1uskontoB2 ovat eniten spekuloineet A1rakkaudenA2 ilmiöllä
Mother	Family	according to the declaration of human rights that covers also A1mothersA2 everyone has right for B1familyB2 life (taken from other part of article)	myös A1äitejäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään
Mother	Father	an adoptive A1motherA2 is the biologically unrelated wife of a child's B1fatherB2 (taken from other part of article)	adoptioA1äitiA2 on ei- biologinen vaimo lapsen B1isälleB2
Mother	Human	in the case of a mammal such as a B1humanB2, the biological A1motherA2 gestates a fertilized ovum	nisäkkäillä, kuten B1ihmiselläB2, biologinen A1äitiA2 kasvattaa hedelmöitetyn munasolun
Mother	Leisure	according to the declaration of human rights that covers also A1mothersA2 everyone has right for B1leisureB2 (taken from other part of article)	myös A1äitejäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2
Mother	Love	concerning A1motherA2 B1loveB2 belongs to relationships of family (taken from other part of article)	A1äitiinA2 liittyen B1rakkausB2 kuuluu perheen ihmissuhteisiin
Mother	Parent	A1motherA2 is a biological or social female B1parentB2 of an offspring	A1äitiA2 on biologinen tai sosiaalinen naispuolinen B1vanhempiB2 lapselle
Mother	Sibling	concerning A1motherA2 B1siblingsB2 belong to members of immediate family (taken from other part of article)	A1äitiinA2 liittyen lähimpiin perheenjäseniin kuuluvat B1sisaruksetB2
Music	Religion	A1musicA2 is performed in rituals such as B1religious processionsB2	A1musiikkiaA2 esitetään rituaaleissa, kuten B1uskontoonB2 liittyvissä seremonioissa
Music	Television	live A1musicA2 can be broadcast over the B1televisionB2	elävää A1musiikkiaA2 voidaan lähettää B1televisionB2 kautta
Nature	Animal	in A1natureA2 properties common to organisms, such as B1animalsB2, are that they are cellular (taken from other part of article)	A1luontoonA2 liittyen eliöille, kuten B1eläimilleB2, yleisiä ominaisuuksia on koostuminen soluista
Nature	Biology	in A1natureA2 B1biologyB2 has a central role for life	A1luonnossaA2 B1biologiallaB2 on keskeinen merkitys elämälle
Nature	Human	in A1natureA2 wilderness is generally defined as an environment that has not been directly modified by B1humanB2 (taken from other part of article)	A1luonnossaA2 erämaana pidetään ympäristöä, jota B1ihminenB2 ei ole suoraan muokannut

Nature	Organism	in A1natureA2 biological manifestation of life concerning B1organismsB2 is characterized by organization (taken from other part of article)	A1luonnossaA2 B1eliöitäB2 koskeva elämä ilmenee biologisesti mm. järjestäytymisenä
Nature	Oxygen	in A1natureA2 dry air consists of 21 percent B1oxygenB2 (taken from other part of article)	A1luonnossaA2 kuiva ilma sisältää 21 prosenttia B1happeaB2
Nature	Plant	in A1natureA2 properties common to organisms, such as B1plantsB2, are that they are cellular (taken from other part of article)	A1luonnossaA2 eliöille, kuten B1kasveilleB2, yleisiä ominaisuuksia on koostuminen soluista
Nature	Sun	concerning A1natureA2 one part of the Earth is more exposed to the rays of the B1SunB2 (taken from other part of article)	A1luontoonA2 liittyen osa maapallosta on enemmän altistettuna B1auringonB2 säteille
Old_age	Adolescence	B1adolescenceB2 is a legally important stage in personal development like A1old ageA2 (taken from other part of article)	B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, kuten A1vanhuusA2
Old_age	Biology	part of B1biologyB2 related to A1ageingA2 is called senescence (taken from other part of article)	A1vanhuuteenA2 liittyvää B1biologianB2 osa-aluetta kutsutaan seneskenssiksi
Old_age	Child	B1childB2 is a legally important stage in personal development like also A1old ageA2 (taken from other part of article)	B1lapsiB2 on oikeudellisesti tärkeässä yksilönkehityksen vaiheessa, jollainen on myös A1vanhuusA2
Old_age	Death	A1old ageA2 is a stage of life preceding B1deathB2 (taken from other part of article)	A1vanhuusA2 on B1kuolemaaB2 edeltävä elämänvaihe
Organism	Biology	in B1biologyB2 an A1organismA2 is an individual living system	B1biologiassaB2 A1eliöA2 on itsenäinen elävä järjestelmä
Organism	Heart	A1organismsA2 have organs to produce a particular function such as the pumping of the blood by the B1heartB2 (taken from other part of article)	A1eliölläA2 on elimiä tiettyjen toimintojen tuottamiseksi, kuten veren pumppaaminen B1sydämelläB2
Organism	Plant	concerning A1organismsA2 about 500 million years ago, B1plantsB2 and fungi colonized the land (taken from other part of article)	A1eliöihinA2 liittyen noin 500 miljoona vuotta sitten B1kasvitB2 ja sienet valloitivat maa-alueet
Oxygen	Automobile	near the earth's surface ozone consisting of A1oxygenA2 is a pollutant formed from B1automobileB2 exhaust (taken from other part of article)	A1hapestA2 koostuva otsoni on maan pinnalla saaste, joka syntyy B1autojenB2 pakokaasuista
Oxygen	Disease	A1oxygen therapy is used to treat B1diseasesB2 that impair the ability to use gaseous oxygen (taken from other part of article)	A1happiA2terapiaa käytetään B1sairauksienB2 hoitoon, jotka vaikeuttavat hapen käyttöä
Oxygen	Heart	A1oxygen therapy is used to treat B1heartB2 disorders (taken from other part of article)	A1happiA2terapiaa käytetään B1sydämenB2 häiriöiden hoitoon
Oxygen	Plant	A1oxygenA2 in the form of O2 is produced from water e.g. by B1plantsB2 during photosynthesis	A1happiA2 muodossa O2 syntyy vedestä mm. B1kasvienB2 yhteyttämisen kautta
Oxygen	Sun	about 0.87 percent of the B1Sun'sB2 mass is from A1oxygenA2	noin 0,87 prosenttia B1auringonB2 massasta on A1happeaA2
Oxygen	Water	B1waterB2 (H2O) is the oxide of hydrogen and the most familiar A1oxygenA2 compound	B1vesiB2 (H2O) on vedyn oksidi ja yleisin A1happiA2yhdiste
Parent	Birth	mother is a A1parentA2 who gives B1birthB2 to an offspring (taken from other part of article)	äiti on A1vanhempiA2, joka synnyttämällä toteuttaa jälkeläisen B1syntymisenB2
Parent	Child	mother is the biological or social female A1parentA2 of a B1childB2	äiti on biologinen tai sosiaalinen naispuolinen A1vanhempiA2 B1lapselleB2
Parent	Father	B1fatherB2 is a A1parentA2 who sires an offspring (taken from other part of article)	B1isäB2 on A1vanhempiA2, joka hoitaa jälkeläistä

Parent	Human	concerning A1parentsA2 in the case of B1humansB2 the mother gestates her child in the uterus (taken from other part of article)	A1vanhempiinA2 liittyen B1ihmisenB2 tapauksessa biologinen äiti kasvattaa lasta kohdussaan
Parent	Mother	B1motherB2 is a A1parentA2 who nurtures an offspring (taken from other part of article)	B1äitiB2 on A1vanhempiaA2, joka hoitaa jälkeläistä
Parent	Sibling	B1siblingsB2 compete about A1parentalA2 investments (taken from other part of article)	B1sisaruksetB2 kilpailevat A1vanhempiansaA2 investoinnista hyvinvointinsa lisäämiseksi
Peace	Education	A1peacefulA2 development can be a set of many different elements such as B1educationB2	A1rauhaaA2 tukeva kehitys voi koostua useasta tekijästä, kuten B1koulutuksestaB2
Peace	War	concerning A1peaceA2 democracies rarely make B1warB2 against each other (taken from other part of article)	A1rauhaanA2 liittyen demokraatit käyvät harvoin B1sotiaB2 toisiaan vastaan
Pet	Animal	A1petA2 is an B1animalB2 kept for companionship	A1lemmikkieläinA2 on B1eläinB2, jota pidetään seuraksi
Pet	Cat	only a small number of species of mammals like B1catB2 is practical as a A1petA2 (taken from other part of article)	vain pieni osa nisäkäslajeista, kuten B1kissaB2, on käytännöllisiä A1lemmikkieläimiksiA2
Pet	Dog	only a small number of species of mammals like B1dogB2 is practical as a A1petA2 (taken from other part of article)	vain pieni osa nisäkäslajeista, kuten B1koiraB2, on käytännöllisiä A1lemmikkieläimiksiA2
Plant	Animal	fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2 (taken from other part of article)	sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2
Plant	Biology	concerning A1plantsA2 in nature B1biologyB2 has a central role for life (taken from other part of article)	A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle
Plant	Light	most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide (taken from other part of article)	useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoaB2 ja hiilidioksidia
Plant	Nature	in B1natureB2 human has contributed to the extinction of many A1plantsA2 (taken from other part of article)	B1luonnossaB2 ihminen on vaikuttanut useiden A1kasvienA2 sukupuuttoon
Plant	Organism	A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees	A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita
Plant	Oxygen	concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2 (taken from other part of article)	A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakehää, jossa on nykyisin 21 prosenttia B1happeaB2
Plant	Tree	among A1plantsA2 conifers are dominant B1treesB2 (taken from other part of article)	A1kasvienA2 joukossa paljassiemeniset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä
Plant	Water	growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2 (taken from other part of article)	A1kasvienA2 kasvu määräytyy myös ympäristötekijöistä, kuten saatavilla olevasta B1vedestäB2
Religion	God	A1religionA2 is related to awareness of B1GodB2 through direct personal experience (taken from other part of article)	A1uskontoonA2 liittyy tietoisuus B1jumalastaB2 suoran henkilökohtaisen kokemuksen kautta
Religion	Human	concerning A1religionA2 B1humansB2 have methods which attempt to answer fundamental questions (taken from other part of article)	A1uskontoaA2 koskien B1ihmisilläB2 on menetelmiä vastauksen saamiseksi perimmäisiin kysymyksiin
Religion	Sun	concerning A1religionA2 Isaac Newton believed that the planets	A1uskontoonA2 liittyen Isaac Newton uskoi, että

		revolve about the B1SunB2 and credited God with the design (taken from other part of article)	planeetat pyörivät B1auringonB2 ympäri jumalan suunnittelutyön seurauksena
School	Education	concerning A1schoolA2 most countries have a system of B1educationB2 which is compulsory (taken from other part of article)	A1kouluunA2 liittyen useimmilla valtioilla on B1koulutusB2järjestelmä, joka on pakollinen
School	Teacher	A1schoolA2 is an institution designed to allow students to learn under the supervision of B1teacherB2 (taken from other part of article)	A1kouluA2 on laitos, joka on suunniteltu, jotta opiskelijat voivat oppia B1opettajanB2 ohjauksessa
Sea	Water	A1seaA2 is a large expanse of saline B1waterB2 (taken from other part of article)	A1meriA2 on suuri alue suolaista B1vettäB2
Sibling	Family	A1siblingA2 bond is influenced by factors such as experiences outside the B1familyB2	suhde A1sisarustenA2 välillä riippuu esim. kokemuksista B1perheenB2 ulkopuolella
Sibling	Father	half sibling that shares the same B1fatherB2 is known as an agnate A1siblingA2	sisarpuolta, joka jakaa saman isän, voidaan kutsua B1isänB2 puolelta tulevaksi A1sisarukseksiA2
Sibling	Love	concerning A1siblingsA2 closeness may be marked with strong emotions such as B1loveB2 (taken from other part of article)	A1sisaruksiinA2 liittyen läheisyyteen voi kuulua voimakkaita tunteita, kuten B1rakkauttaB2
Sibling	Mother	half sibling that shares the same B1motherB2 is known as a uterine A1siblingA2	sisarpuolta, joka jakaa saman äidin, voidaan kutsua B1äidinB2 puolelta tulevaksi A1sisarukseksiA2
Sibling	Parent	A1siblingA2 is brother or sister with whom a person shares at least one B1parentB2 (taken from other part of article)	henkilön A1sisarusA2 on veli tai sisko, jonka kanssa hän jakaa ainakin yhden B1vanhemmanB2
Sun	Oxygen	surface composition of the A1SunA2 consists of hydrogen, helium and trace quantities of other elements like B1oxygenB2 (taken from other part of article)	A1auringonA2 pinta koostuu vedystä, heliumista ja pienistä määristä muita aineita, kuten B1happeaB2
Sun	Plant	photosynthesis by B1plantsB2 captures A1sunA2light and converts it to chemical form (taken from other part of article)	B1kasvienB2 yhteyttäminen kerää A1auringonA2valoa ja muuntaa sen kemialliseen muotoon
Teacher	Education	in B1educationB2 A1teachersA2 facilitate learning of students (taken from other part of article)	B1koulutuksessaB2 A1opettajatA2 helpottavat opiskelijoiden oppimista
Teacher	Learning	the objective for a A1teacherA2 is typically to teach a course of study and B1learningB2 skills (taken from other part of article)	A1opettajanA2 tavoiteena on usein opettaa kurssi sekä B1oppimisenB2 taitoja
Teacher	School	in education A1teachersA2 facilitate learning of students in B1schoolB2 (taken from other part of article)	koulutuksessa A1opettajatA2 helpottavat opiskelijoiden oppimista B1koulussaB2
Tree	Oxygen	A1treesA2 have been found to play an important role in producing B1oxygenB2 (taken from other part of article)	A1puillaA2 on havaittu olevan tärkeä tehtävä B1hapenB2 tuottamisessa
Tree	Water	roots of a A1treeA2 are generally embedded in earth absorbing B1waterB2 from the soil (taken from other part of article)	A1puidenA2 juuret sijaitsevat yleensä maan sisässä imien B1vettäB2 maaperästä
War	Disease	growth of population is limited by A1warA2 as well as B1diseasesB2 (taken from other part of article)	A1sotaA2 rajoittaa väestönkasvua, kuten myös B1sairaudetB2
War	Peace	theories of A1warA2 must explain also B1peaceB2 (taken from other part of article)	A1sotaaA2 koskevien teorioiden tulee selittää myös B1rauhaaB2
War	Religion	acceptance of A1warA2 is inculcated into humans by e.g. B1religiousB2 surroundings in which they live (taken from other	ihmiset omaksuvat A1sodanA2 hyväksynnän mm. elinympäristön B1uskonnostaB2

		part of article)	
Water	Biology	from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life (taken from other part of article)	B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiseksi
Water	Human	storage of A1waterA2 is important, since it is essential to B1humanB2 life (taken from other part of article)	A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle
Water	Organism	existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2 (taken from other part of article)	A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2
Water	Oxygen	components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe (taken from other part of article)	A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa
Water	Plant	there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2 (taken from other part of article)	A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta
Water	Sea	liquid A1waterA2 is found in bodies of water such as B1seaB2 (taken from other part of article)	nestemäistä A1vettäA2 esiintyy vesistöissä, kuten B1meressäB2
Water	Sun	the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2 (taken from other part of article)	maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa
Water	Travel	concerning A1waterA2 rivers and seas offer opportunity for B1travelB2 (taken from other part of article)	A1veteenA2 liittyen joet ja meret tarjoavat tilaisuuden B1matkustamiselleB2

Additional hyperlinks for rolling back

14 hyperlinks in addition to 212 above mentioned hyperlinks that were traversed to roll back to previously visited concept when the student's exploration had lead to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration:

<i>Hyperlink</i>	<i>Number of traversals</i>
Disease->Oxygen	1
Experience->Emotion	18
Experience->Learning	8
Happiness->Love	4
Heart->Organism	6
Heart->Death	5
Joy->Emotion	7
Learning->Teacher	3
Television->Adolescence	3
Television->Clothing	1
Television->Light	1
Television->Leisure	1
Travel->Water	3
Work->Leisure	5

Appendix K

Listing of the highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), shown for all students and also separately for male students (n=18) and female students (n=31). Exploration experiment with students was carried out in “hyperlink network of 55 concepts” containing 212 hyperlinks connecting 55 concepts. All 212 hyperlinks of “hyperlink network of 55 concepts” are connecting concepts that are reachable (by traversing one or more intermediate hyperlinks) from concept Human in exploration paths (containing 55 concepts including concept Human). This listing shows the number of traversals for those hyperlinks of 212 hyperlinks that became traversed by students and as well as for additional roll back hyperlinks (shown in Appendix J). Please note that in exploration experiment each student was allowed to traverse each hyperlink belonging to “hyperlink network of 55 concepts” at most once (except in case of roll back hyperlinks).

This listing also shows for all students the number of selectable alternative hyperlinks (average) shown to the student when she selected to traverse a hyperlink that was just before traversing current hyperlink. The number of traversals for hyperlinks departing from Human includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis is shown the number of traversals when excluding hyperlinks departing from concept Human that were the student’s first traversed hyperlink in exploration path. Indicated with an asterisk (*), for hyperlinks departing from concept Human the number of selectable alternative hyperlinks (average) is calculated only based on those traversals of hyperlinks departing from concept Human that were not the student’s first traversed hyperlink in her exploration path. Among 16 alternative hyperlinks departing from concept Human there did not occur any traversals for hyperlinks Human->God and Human->Old_age.

<i>All students participating in exploration task (n = 49)</i>			<i>All male students participating in exploration task (n = 18)</i>		<i>All female students participating in exploration task (n = 31)</i>	
<i>Traversed hyperlink (current hyperlink)</i>	<i>Number of traversals</i>	<i>Number of selectable alternative hyperlinks (average) shown to student when she selected to traverse a <u>hyperlink that was just before</u> traversing current hyperlink</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>	<i>Traversed hyperlink</i>	<i>Number of traversals</i>
Happiness -> Emotion	29	3.758621	Animal -> Nature	4	Happiness -> Emotion	25
Emotion -> Love	26	1.846154	Joy -> Happiness	4	Emotion -> Love	23
Joy -> Happiness	24	2.125	Happiness -> Joy	4	Disease -> Death	22
Disease -> Death	24	4.625	Happiness -> Emotion	4	Joy -> Happiness	20
Happiness -> Joy	21	4.285714	Sun -> Oxygen	3	Adolescence -> Education	17
Human -> Diet (nutrition)	19 (2*)	5.5*	Sun -> Plant	3	Happiness -> Joy	17
Emotion -> Experience	19	7.263158	Biology -> Animal	3	Human -> Diet (nutrition)	16
Experience -> Emotion (only to roll back)	18	3.833333	Organism -> Biology	3	Emotion -> Experience	16
Organism -> Biology	17	5.176471	Organism -> Plant	3	Experience -> Emotion (only to roll back)	15
Adolescence ->	17	6.764706	Organism -> Heart	3	Organism ->	14

Education						Biology	
Love -> Friendship	16	2.75		Oxygen -> Sun	3	Education -> Learning	14
Education -> Learning	14	3.428571		Oxygen -> Plant	3	Learning -> Education	14
Learning -> Education	14	5.642857		Oxygen -> Water	3	Love -> Friendship	14
Emotion -> Happiness	14	3.571429		Human -> Diet (nutrition)	3	Family -> Mother	12
Family -> Mother	13	8.384615		Plant -> Nature	3	Health -> Disease	12
Diet (nutrition) -> Health	13	14.92308		Plant -> Tree	3	Diet (nutrition) -> Health	11
Health -> Disease	13	10.38462		Experience -> Emotion (only to roll back)	3	Emotion -> Happiness	11
Love -> Happiness	11	6.363636		Happiness -> Love (only to roll back)	3	Emotion -> Joy	10
Emotion -> Joy	11	2.090909		Love -> Happiness	3	Friendship -> Adolescence	10
Love -> Emotion	10	5.4		Emotion -> Experience	3	Biology -> Nature	9
Friendship -> Adolescence	10	5.3		Emotion -> Happiness	3	Human -> Adolescence	9
Biology -> Nature	9	3.444444		Emotion -> Love	3	Adolescence -> Child	9
Organism -> Plant	9	4.888889		Automobile -> Oxygen	2	Love -> Emotion	9
Oxygen -> Water	9	6.333333		Animal -> Organism	2	Human -> Family	8
Human -> Adolescence	9 (2*)	7*		Oxygen -> Automobile	2	Human -> Emotion	8
Human -> Family	9 (6*)	7.333333*		Death -> Organism	2	Experience -> Learning (only to roll back)	8
Human -> Emotion	9 (3*)	6		Nature -> Animal	2	Death -> Disease	8
Adolescence -> Child	9	9.555556		Nature -> Human	2	Death -> War	8
Sun -> Plant	8	5.375		Travel -> Water	2	Learning -> Experience	8
Organism -> Heart	8	5.875		Family -> Father	2	Love -> Happiness	8
Human -> Health	8 (3*)	6.666667*		Tree -> Oxygen	2	War -> Peace	8
Experience -> Learning (only to roll back)	8	1.75		Love -> Biology	2	Biology -> Organism	7
Death -> Disease	8	1.75		Love -> Friendship	2	Human -> Health	7
Death -> War	8	1.75		Diet (nutrition) -> Organism	2	Family -> Sibling	7
Learning -> Experience	8	7.375		Diet (nutrition) -> Health	2	Love -> Family	7
Love -> Family	8	3.5		Disease -> Death	2	Organism -> Plant	6
War -> Peace	8	8.5		Sibling -> Love	2	Animal -> Human	6
Mother -> Parent	8	4.5		Heart -> Organism	2	Oxygen -> Water	6
Biology -> Organism	7	5.857143		Health -> Diet (nutrition)	2	Joy -> Emotion (only to roll back)	6
Biology -> Animal	7	4.142857		Parent -> Sibling	2	School -> Education	6
Oxygen -> Plant	7	6		Water -> Oxygen	2	Education -> School	6
Joy -> Emotion (only to roll back)	7	1.142857		Water -> Travel	2	Education -> Adolescence	6
Plant -> Tree	7	2.571429		Friendship -> Animal	2	Education -> Leisure	6
Sea -> Water	7	7.857143		Mother -> Parent	2	Death -> Human	6
Family -> Sibling	7	9.428571		Biology -> Human	1	Child -> Family	6
Sibling -> Love	7	5.571429		Biology -> Plant	1	Sea -> Water	6
Water -> Sea	7	6.428571		Animal -> Oxygen	1	Teacher -> Learning	6
Sun -> Oxygen	6	3.5		Animal -> Water	1	Family -> Child	6
Animal -> Human	6	5.666667		Oxygen -> Disease	1	Peace -> Education	6
Animal -> Nature	6	7.333333		Human -> Oxygen	1	Water -> Sea	6
Human -> Happiness	6 (5*)	6.6*		Human -> Happiness	1	Mother -> Parent	6
Plant -> Nature	6	4.333333		Human -> Family	1	Sun -> Plant	5
Plant -> Light	6	3.5		Human -> War	1	Organism -> Heart	5
School ->	6	3.5		Human -> Health	1	Human ->	5

Education						Happiness	
Education -> School	6	2.833333		Human -> Emotion	1	Plant -> Light	5
Education -> Adolescence	6	2		Human -> Religion	1	Education -> Human	5
Education -> Leisure	6	1.833333		Joy -> Emotion (only to roll back)	1	Education -> Teacher	5
Death -> Organism	6	1		Father -> Family	1	Child -> Adolescence	5
Death -> Human	6	1.333333		Father -> Sibling	1	Teacher -> School	5
Child -> Family	6	3.333333		Father -> Mother	1	Sibling -> Love	5
Teacher -> Learning	6	5.5		God -> Father	1	Health -> Biology	5
Family -> Child	6	6.5		Plant -> Biology	1	Work -> Leisure (only to roll back)	5
Peace -> Education	6	3		Plant -> Animal	1	Parent -> Human	5
Diet_(nutrition) -> Organism	6	13.833333		Plant -> Light	1	Parent -> Birth	5
Heart -> Organism (only to roll back)	6	2.333333		Plant -> Water	1	Leisure -> Work	5
Mother -> Love	6	4.833333		Death -> Heart	1	Mother -> Love	5
Biology -> Human	5	4.8		Nature -> Sun	1	Biology -> Animal	4
Human -> War	5 (3*)	5.666667*		Nature -> Organism	1	Biology -> Human	4
God -> Father	5	3		Nature -> Oxygen	1	Oxygen -> Plant	4
Education -> Human	5	2.2		Sea -> Water	1	Human -> War	4
Education -> Teacher	5	2.4		Family -> Mother	1	Father -> Love	4
Death -> Heart	5	1.6		Tree -> Water	1	God -> Father	4
Child -> Adolescence	5	5.2		Love -> Family	1	Plant -> Tree	4
Teacher -> School	5	4.2		Love -> Emotion	1	School -> Teacher	4
Tree -> Oxygen	5	7.4		Diet_(nutrition) -> Religion	1	Death -> Organism	4
Love -> Biology	5	1.6		Disease -> Oxygen (only to roll back)	1	Death -> Heart	4
Heart -> Death (only to roll back)	5	6.6		Sibling -> Parent	1	Child -> Parent	4
Health -> Biology	5	4		War -> Disease	1	Adolescence -> Old_age	4
Work -> Leisure (only to roll back)	5	4.8		Heart -> Death (only to roll back)	1	Family -> Leisure	4
Religion -> God	5	2.4		Health -> Disease	1	Diet_(nutrition) -> Organism	4
Light -> Sun	5	6.2		Emotion -> Joy	1	War -> Religion	4
Parent -> Human	5	6		Religion -> Sun	1	Heart -> Organism	4
Parent -> Birth	5	6.4		Religion -> God	1	Heart -> Death (only to roll back)	4
Leisure -> Work	5	5.2		Light -> Sun	1	Religion -> God	4
Animal -> Organism	4	4.25		Parent -> Mother	1	Light -> Sun	4
Father -> Love	4	4.75		Water -> Sun	1	Leisure -> Family	4
School -> Teacher	4	9.5		Water -> Human	1	Sun -> Oxygen	3
Child -> Parent	4	4.25		Water -> Plant	1	Human -> Love	3
Nature -> Animal	4	6.5		Water -> Sea	1	Human -> Clothing	3
Nature -> Human	4	6.25		Mother -> Love	1	Plant -> Organism	3
Adolescence -> Old_age	4	9.25				Plant -> Nature	3
Happiness -> Love	4	3				Nature -> Plant	3
Family -> Father	4	5.75				Adolescence -> Television	3
Family -> Leisure	4	7.75				Learning -> Teacher (only to roll back)	3
War -> Religion	4	6.75				Tree -> Oxygen	3
Health -> Diet_(nutrition)	4	7.5				Love -> Biology	3
Leisure -> Family	4	5.25				Diet_(nutrition) -> Death	3
Water -> Sun	4	2.75				Birth -> Animal	3
Oxygen -> Sun	3	5				Television -> Adolescence (only to roll back)	3

Oxygen -> Disease	3	1.333333			Religion -> Human	3
Human -> Love	3 (2*)	7.5*			Old_age -> Death	3
Human -> Religion	3 (0*)	not available since no other hyperlinks were traversed before traversing Human -> Religion*			Water -> Sun	3
Human -> Clothing	3 (2*)	6*			Biology -> Health	2
Father -> Family	3	3.666667			Animal -> Organism	2
Plant -> Organism	3	3			Animal -> Nature	2
Plant -> Water	3	3.333333			Oxygen -> Disease	2
Nature -> Sun	3	6			Oxygen -> Heart	2
Nature -> Organism	3	6.333333			Human -> House	2
Nature -> Oxygen	3	6.666667			Human -> Religion	2
Nature -> Plant	3	6.333333			Father -> Family	2
Travel -> Water	3	7			Father -> Parent	2
Adolescence -> Television	3	7.333333			Plant -> Oxygen	2
Learning -> Teacher (only to roll back)	3	1.666667			Plant -> Water	2
Diet_(nutrition) -> Death	3	12			Home -> Family	2
Sibling -> Parent	3	3.666667			Education -> Biology	2
War -> Disease	3	12.333333			Death -> Oxygen	2
Birth -> Animal	3	6			Nature -> Sun	2
Television -> Adolescence (only to roll back)	3	3.333333			Nature -> Organism	2
Religion -> Human	3	11.333333			Nature -> Animal	2
Old_age -> Death	3	4.333333			Nature -> Oxygen	2
Water -> Oxygen	3	3.333333			Nature -> Human	2
Water -> Plant	3	1			Family -> Father	2
Water -> Travel	3	2			Peace -> War	2
Automobile -> Oxygen	2	6			Sibling -> Family	2
Biology -> Plant	2	2.5			Sibling -> Parent	2
Biology -> Health	2	3			War -> Disease	2
Oxygen -> Automobile	2	2			House -> Home	2
Oxygen -> Heart	2	3.5			Health -> Diet_(nutrition)	2
Human -> Oxygen	2 (1*)	7*			Clothing -> Religion	2
Human -> House	2 (1*)	3*			Light -> Television	2
Father -> Parent	2	5			Parent -> Father	2
Father -> Mother	2	4.5			Parent -> Child	2
Plant -> Biology	2	6			Leisure -> Education	2
Plant -> Animal	2	5			Leisure -> Sibling	2
Plant -> Oxygen	2	7			Water -> Biology	2
Home -> Family	2	4			Water -> Plant	2
Education -> Biology	2	3			Friendship -> Love	2
Death -> Oxygen	2	2.5			Mother -> Father	2
Tree -> Water	2	6			Biology -> Plant	1
Peace -> War	2	3			Human -> Animal	1
Sibling -> Family	2	4.5			Human -> Oxygen	1
House -> Home	2	15.5			Human -> Music	1
Religion -> Sun	2	9			Father -> Mother	1
Clothing -> Religion	2	8.5			Plant -> Biology	1
Light -> Television	2	8			Plant -> Animal	1
Parent -> Father	2	7			Education -> Sibling	1
Parent -> Child	2	5			Child -> Old_age	1
Parent -> Sibling	2	6			Child -> Leisure	1
Leisure ->	2	1			Travel -> Water	1

Education							
Leisure -> Sibling	2	6				Happiness -> Love (only to roll back)	1
Water -> Biology	2	3.5				Teacher -> Education	1
Friendship -> Animal	2	5.5				Tree -> Water	1
Friendship -> Love	2	5.5				Food -> Human	1
Mother -> Father	2	5				Birth -> Death	1
Animal -> Oxygen	1	7				Birth -> Mother	1
Animal -> Water	1	7				Television -> Clothing (only to roll back)	1
Human -> Animal	1 (0*)	not available since no other hyperlinks were traversed before traversing Human -> Animal*				Television -> Light (only to roll back)	1
Human -> Music	1 (1*)	9*				Television -> Leisure (only to roll back)	1
Father -> Sibling	1	5				Health -> Food	1
Education -> Sibling	1	2				Religion -> Sun	1
Child -> Old_age	1	4				Clothing -> Television	1
Child -> Leisure	1	5				Old_age -> Adolescence	1
Teacher -> Education	1	2				Leisure -> Television	1
Diet_ (nutrition) -> Religion	1	4				Water -> Oxygen	1
Food -> Human	1	3				Water -> Travel	1
Disease -> Oxygen (only to roll back)	1	5				Mother -> Family	1
Birth -> Death	1	6					
Birth -> Mother	1	6					
Television -> Clothing (only to roll back)	1	2					
Television -> Light (only to roll back)	1	2					
Television -> Leisure (only to roll back)	1	5					
Health -> Food	1	4					
Clothing -> Television	1	15					
Parent -> Mother	1	7					
Old_age -> Adolescence	1	4					
Leisure -> Television	1	10					
Water -> Human	1	6					
Mother -> Family	1	3					

Appendix L

Based on Appendix K we have identified the most actively traversed departing and arriving hyperlinks for each of 55 concepts in “hyperlink network of 55 concepts” during exploration experiment with students (n=49). For arriving hyperlinks we express the number of unique end concepts that have got traversed arrivals during surfing per unique end concepts that could have got traversed arrivals in “hyperlink network of 55 concepts” for observed concept, and we also express the end concept for most actively traversed hyperlink departing from observed concept. For departing hyperlinks we express the number of unique start concepts that have got traversed departures during surfing per unique start concepts that could have got traversed departures in “hyperlink network of 55 concepts” for observed concept, and we also express the start concept for most actively traversed hyperlink arriving to observed concept.

If several hyperlinks of observed concept share the position as the most actively traversed departing hyperlink or the most actively traversed arriving hyperlink all corresponding end concepts or start concepts are listed in the table (for example both hyperlinks Animal->Human and Animal->Nature depart from concept Animal and both links Animal->Human and Death->Human arrive at concept Human). For some observed concepts some of traversed departing or arriving hyperlinks are traversals of rolling back and in these cases the values and concepts (if there are any) are listed also without traversals of rolling back, and also hyperlinks traversed for rolling back are listed.

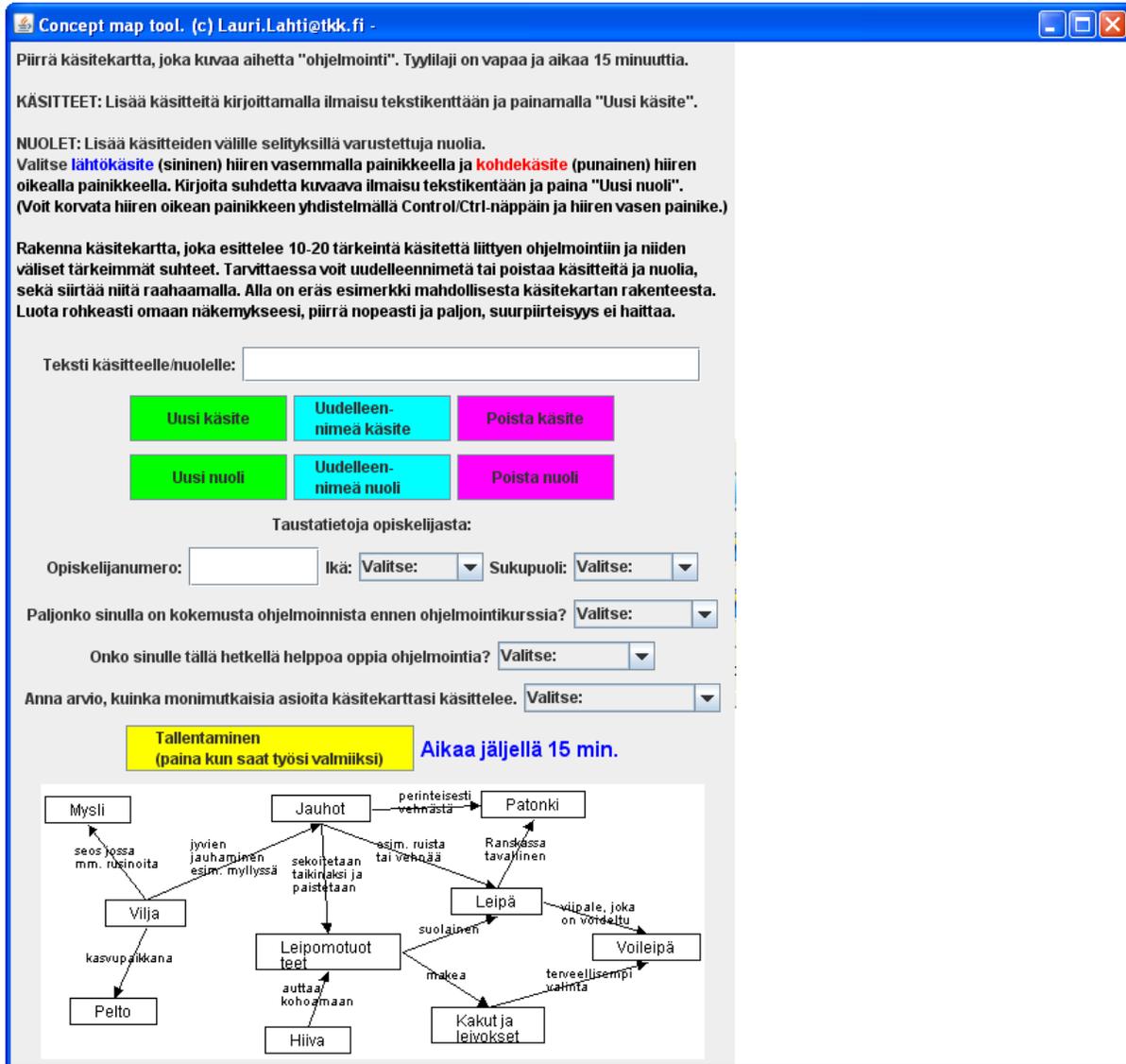
Observed concept	Arriving hyperlinks of “hyperlink network of 55 concepts”		Departing links of “hyperlink network of 55 concepts”	
<i>Concept among 55 concepts of “hyperlink network of 55 concepts”</i>	<i>The number of unique end concepts that have got traversed arrivals during surfing per number of unique end concepts that could have got traversed arrivals in “hyperlink network of 55 concepts” for observed concept</i>	<i>End concept for most actively traversed hyperlink departing from observed concept (N/A = not available)</i>	<i>The number of unique start concepts that have got traversed departures during surfing per number of unique start concepts that could have got traversed departures in “hyperlink network of 55 concepts” for observed concept</i>	<i>Start concept for most actively traversed hyperlink arriving to observed concept (N/A = not available)</i>
Adolescence	4per4	Education	6per6 (without traversals of rolling back 5per6 (rolling back television->adolescence))	Friendship
Animal	5per7	Human; Nature	6per8	Biology
Automobile	1per1	Oxygen	1per1	Oxygen
Biology	6per6	Nature	6per9	Organism
Birth	3per4	Animal	1per1	Parent
Cat	0per3	N/A	0per2	N/A
Child	5per6	Family	3per5	Adolescence
Clothing	2per2	Religion	2per1 (without traversals of rolling back 1per1 (rolling back television->clothing))	Human
Computer	0per2	N/A	0per1	N/A
Death	6per7	Disease; War	5per5 (without traversals of rolling back 4per5 (rolling back heart->death))	Disease
Diet (nutrition)	4per4	Health	2per4	Human
Disease	2per1 (without traversals of rolling back 1per1 (rolling back disease->oxygen))	Death	4per4	Health
Dog	0per3	N/A	0per2	N/A
Education	8per10	Learning	6per6	Adolescence
Emotion	4per4	Love	5per3 (without traversals of rolling back 3per3 (rolling back experience->emotion; joy->emotion))	Happiness
Experience	2per0 (without traversals of rolling back 0per0 (rolling	Emotion (without traversals of rolling	2per2	Emotion

	back experience->learning; experience->emotion))	back N/A)		
Family	5per5	Mother	8per10	Human
Father	5per5	Love	4per5	God
Food	1per10	Human	1per1	Health
Friendship	3per3	Adolescence	1per1	Love
God	1per3	Father	1per2	Religion
Happiness	3per2 (without traversals of rolling back 2per2 (rolling back happiness->love))	Emotion	4per4	Joy
Health	4per4	Disease	3per4	Diet (nutrition)
Heart	2per0 (without traversals of rolling back 0per0 (rolling back heart->organism; heart- >death))	Organism (without traversals of rolling back N/A)	3per3	Organism
Home	1per3	Family	1per1	House
House	1per4	Home	1per2	Human
Human	14per16	Diet (nutrition)	9per11	Animal; Death
Joy	2per1 (without traversals of rolling back 1per1 (rolling back joy->emotion))	Happiness	2per2	Happiness
Learning	3per2 (without traversals of rolling back 2per2 (rolling back learning->teacher))	Education	3per2 (without traversals of rolling back 2per2 (rolling back experience- >learning))	Education
Leisure	5per5	Work	5per4 (without traversals of rolling back 3per4 (rolling back television- >leisure; work->leisure))	Education
Light	2per2	Sun	2per1 (without traversals of rolling back 1per1 (rolling back television- >light))	Plant
Love	5per6	Friendship	7per7 (without traversals of rolling back 6per7 (rolling back happiness- >love))	Emotion
Mother	4per7	Parent	4per5	Family
Music	0per2	N/A	1per1	Human
Nature	6per7	Animal; Human	3per4	Biology
Old_age	2per4	Death	2per3	Adolescence
Organism	3per3	Biology	7per7 (without traversals of rolling back 6per7 (rolling back heart- >organism))	Biology
Oxygen	6per6	Water	10per9 (without traversals of rolling back 9per9 (rolling back disease->oxygen))	Sun
Parent	6per6	Human; Birth	4per4	Mother
Peace	2per2	Education	1per1	War
Pet	0per3	N/A	0per3	N/A
Plant	8per8	Tree	6per8	Organism
Religion	3per3	God	4per7	War
School	2per2	Education	2per3	Education
Sea	1per1	Water	1per1	Water
Sibling	3per5	Love	5per7	Family
Sun	2per2	Plant	5per6	Light
Teacher	3per3	Learning	3per2 (without traversals of rolling back 2per2 (rolling back learning- >teacher))	Education
Telephone	0per0	N/A	0per1	N/A
Television	4per0 (without traversals of rolling back 0per0 (rolling back television- >adolescence; television- >clothing; television->light; television->leisure))	Adolescence (without traversals of rolling back N/A)	4per7	Adolescence
Travel	1per0 (without traversals of rolling back 0per0 (rolling back travel->water))	Water (without traversals of rolling back N/A)	1per1	Water
Tree	2per2	Oxygen	1per1	Plant
War	3per3	Peace	3per4	Death
Water	7per8	Sea	6per6 (without traversals of rolling back 5per6 (rolling back travel-	Oxygen

			>water))	
Work	1per0 (without traversals of rolling back 0per0 (rolling back work->leisure))	Leisure (without traversals of rolling back N/A)	1per1	Leisure

Appendix M

User interface of a prototype tool used by 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming” (texts provided only in Finnish), as discussed in Subchapter 8.2.



English translation of texts of the user interface:

Draw a concept map that describes topic "programming". Presentation style is free and available time 15 minutes.

CONCEPTS: Add concepts by drawing an expression to text field and pressing "New concept".

ARROWS: Add between concepts arrows supplied with descriptions. Select start concept (blue) with left mouse button and end concept (red) with right mouse button. Write expression that describes relation to text field and press "New arrow". (You can replace right mouse button with combination Control/Ctrl button and left mouse button.)

Build a concept map that presents 10-20 most important concepts concerning programming and the most important relationships between them. If needed you can rename or remove concepts and arrows and move

them by dragging. Below is an example of possible structure of a concept map. Have a confidence with your own opinion, draw fast and a lot, approximateness is not a problem.

Text for concept/arrow.

New concept, rename concept, remove concept, new arrow, rename arrow, remove arrow.

Background information about the student.

Student number. Age (select), gender (select).

How much you have experience about programming before participating programming course? (select).

Is it easy for you at the moment to learn programming? (select).

Please give an estimate about how complex things your concept map is dealing with? (select).

Saving (press when you have finished your work). Time left 15 min.

(An example of concept map structure.)

Responses of 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming”. After eliminating unclear responses and transforming all concepts to non-conjugated base forms, there were 167 unique concepts and 167 unique conceptual relationships between them mentioned by at least two students. Both a listing of these unique concepts and a listing of these unique conceptual relationships are shown in table below showing number of occurrences in all 147 concept maps.

<i>Concept</i>	<i>Occurrences (at most one occurrence counted for each student)</i>		<i>Conceptual relationship</i>	<i>Occurrences (at most one occurrence counted for each student)</i>
programming	90		object -> method	29
object	62		class -> object	27
method	60		programming -> programming language	27
java	57		programming language -> java	18
class	49		programming -> language	17
program	47		class -> method	14
programming language	44		java -> object	14
variable	41		programming -> program	14
python	31		object -> variable	12
c	29		language -> java	11
programmer	25		language -> c	10
language	24		program -> class	10
object-oriented programming	22		object -> class	9
computer	21		variable -> object	9
user	21		java -> object-oriented programming	8
compiler	20		language -> python	8
c++	19		programming language -> c	8
code	17		programming -> object	8
user interface	16		programming -> object-oriented programming	8
loop	13		programming language -> python	7
debugger	12		class -> variable	6
eclipse	12		method -> object	6
problem	11		object-oriented programming -> java	6
algorithm	9		programming -> computer	6
conditional sentence	9		programming -> java	6
int	9		programming -> tool	6
parameter	9		c -> C++	5
program code	9		code -> program	5
ready program	9		java -> class	5
starting method	9		method -> class	5
tool	9		method -> variable	5
library	8		package -> class	5
machine language	8		programmer -> program	5
testing	8		programmer -> programming	5
constructor	7		programmer -> programming language	5
list	7		programming -> programmer	5
string	7		programming -> user interface	5

double	6		programming -> variable	5
function	6		variable -> method	5
gui	6		class -> constructor	4
operating system	6		code -> compiler	4
planning	6		java -> variable	4
assembly	5		object-oriented programming -> object	4
bug	5		program -> user	4
debugging	5		programming language -> c++	4
grafical user interface	5		programming -> code	4
hardware	5		programming -> python	4
instance variable	5		user -> program	4
package	5		c -> language	3
php	5		java -> language	3
prosessor	5		java -> method	3
application generator	4		language -> assembly	3
boolean	4		language -> paradigm	3
command	4		loop -> for	3
editor	4		loop -> while	3
information structure	4		method -> value	3
internet	4		object -> list	3
javascript	4		object-oriented programming -> class	3
lecture	4		object-oriented programming -> python	3
mathematics	4		problem -> programming	3
memory	4		program code -> object	3
paradigm	4		program -> code	3
primitive type	4		program -> library	3
primitive variable	4		program -> object	3
programming environment	4		program -> operating system	3
source code	4		program -> user interface	3
syntax	4		programmer -> code	3
value	4		programming language -> code	3
abstraction level	3		programming language -> machine language	3
aim	3		programming language -> object-oriented programming	3
application	3		programming -> assistive tool	3
application program	3		programming -> user	3
assistive tool	3		python -> language	3
basic	3		python -> object	3
char	3		tool -> compiler	3
client	3		tool -> debugger	3
coding	3		user -> code	3
concept	3		variable -> instance	3
for	3		variable -> local	3
functional programming	3		abstraction level -> high	2
functioning of program	3		abstraction level -> low	2
functioning program	3		assistive tool -> debugger	2
human	3		assistive tool -> eclipse	2
if	3		c++ -> language	2
instance	3		c++ -> object-oriented programming	2
keeper of the most recent	3		c++ -> program	2
local	3		class -> program code	2
logic	3		code -> programming language	2
parsing	3		compiler -> machine language	2
plan	3		computer -> code	2
structure	3		computer -> program	2
task	3		computer -> programming	2
while	3		eclipse -> debugger	2
virtual machine	3		editor -> code	2
visual basic	3		information -> variable	2
agile	2		input -> method	2
artificial intelligence	2		java -> concept	2
asm	2		java -> eclipse	2
basic data type	2		java -> loop	2
book	2		java -> program	2
c language	2		language -> c++	2
c#	2		library -> class	2
c/c++	2		loop -> do	2
clarity	2		loop -> programming	2

coder	2		memory -> processor	2
computation	2		method -> output	2
computer program	2		method -> parameter	2
constructor parameter	2		object -> algorithm	2
database	2		object -> object	2
development	2		object -> parameter	2
do	2		object -> programming	2
documentation	2		object-oriented programming -> variable	2
else	2		parameter -> method	2
environment	2		plan -> program code	2
example	2		primitive type -> boolean	2
for example java	2		problem -> program	2
function programming	2		problem -> programming language	2
function-based	2		program code -> class	2
google	2		program code -> variable	2
grafical	2		program -> application	2
hardware level	2		program -> bug	2
high	2		program -> compiler	2
history	2		program -> function	2
i	2		program -> hardware	2
ide	2		program -> method	2
information	2		program -> other programmer	2
information processing	2		program -> tool	2
input	2		program -> variable	2
integer	2		programmer -> user	2
java programming	2		programming environment -> eclipse	2
keeper of the most suitable	2		programming language -> php	2
local variable	2		programming language -> programming	2
logic operator	2		programming -> abstraction level	2
logic thinking	2		programming -> algorithm	2
loosing attention	2		programming -> c	2
low	2		programming -> c++	2
machine	2		programming -> class	2
not working	2		programming -> compiler	2
object-based	2		programming -> computer program	2
other	2		programming -> function	2
other language	2		programming -> information structure	2
other object	2		programming -> logic	2
other programmer	2		programming -> machine language	2
output	2		programming -> mathematics	2
pascal	2		programming -> method	2
private	2		programming -> other language	2
problem/task	2		programming -> program code	2
procedural programming	2		programming -> programming environment	2
public	2		programming -> style	2
result	2		programming -> theory	2
returning of value	2		processor -> program	2
role	2		starting method -> class	2
scheme	2		structure -> conditional sentence	2
software	2		testing -> programming	2
solution	2		tool -> application generator	2
studying	2		user interface -> grafical	2
style	2		user interface -> program	2
syntax error	2		user interface -> text-based	2
table	2		user interface -> user	2
text-based	2		user -> programmer	2
theory	2		variable -> class	2
type	2		variable -> double	2
utility program	2		variable -> instance variable	2
waterfall	2		variable -> int	2
web	2		variable -> keeper of the most recent	2
void	2		variable -> keeper of the most suitable	2
working life	2		variable -> parameter	2

This is a listing of response alternatives for self-evaluation of 147 university students of introductory Java programming course who we asked to draw with our method concept maps representing their knowledge about learning topic “programming” (analysis of responses given by students is discussed in Subchapter 8.2)

For three questions the student replied by selecting a most suitable answer from a scale of five given alternatives that are listed here next.

Response alternatives for question “How much you have experience about programming before participating introductory programming course?” (it can be expected to be clear for the students from the context that this question refers specifically to their current introductory programming course):

Very much; Much; Moderately; Little; or Very little.

(In Finnish: Paljonko sinulla on kokemusta ohjelmoinnista ennen ohjelmontikurssi?

Erittäin paljon; Paljon; Kohtalaisesti; Vähän; tai Erittäin vähän.)

Response alternatives for question “Is it easy for you at the moment to learn programming?”:

Very easy; Easy; Moderate; Difficult; or Very difficult.

(In Finnish: Onko sinulle tällä hetkellä helppoa oppia ohjelmointia?

Erittäin helppoa; Helppoa; Kohtalaista; Vaikeaa; tai Erittäin vaikeaa.)

Response alternatives for question “Please give an estimate about how complex things your concept map is dealing with?”:

Very complex; Complex; Moderate; Simple; or Very simple.

(In Finnish: Anna arvio, kuinka monimutkaisia asioita käsittekarttasi käsittelee.

Erittäin monimutkaisia; Monimutkaisia; Kohtalaisia; Yksinkertaisia; tai Erittäin yksinkertaisia.)

Appendix N

This listing is based on listings of Table 3.9 and Appendix K to enable comparing the highest-ranking core relationships in concept maps drawn by students (n=103) and traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), and to identify those relationships that exist in both listings, indicated with an asterisk (*).

In columns 1-3 is a list of 145 core relationships that are in fact all those relationships between 102 core concepts extended with concept “brother” that are mentioned by at least two students in concept maps drawn by students (n=103), shown in descending order of occurrences in concept maps (based on Table 3.9). However to enable comparison with knowledge structures of the Wikipedia, each concept was transformed to the closest matching entry of Wikipedia articles according to listing of Appendix F which also explains why Sibling is used to represent concept “brother”. Since relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order.

In columns 4-6 is a list of highest-ranking traversed hyperlinks of the Wikipedia in exploration paths of students (n=49), shown for all students (based on Appendix K). Exploration experiment with students was carried out in “hyperlink network of 55 concepts” containing 212 hyperlinks connecting 55 concepts. The number of traversals for hyperlinks departing from Human (for example for Human -> Diet_(nutrition) value 19) includes all those traversals that originate from the fact that in the experiment all exploration paths of students had to start always from concept Human, however in parenthesis (for example for Human -> Diet_(nutrition) value 2) is shown the number of traversals when excluding hyperlinks departing from concept Human that were the student’s first traversed hyperlink in exploration path.

Hyperlinks supplied with notation “only to roll back” belong to 14 hyperlinks (shown in Appendix J) that supplement 212 hyperlinks of “hyperlink network of 55 concepts” and were traversed to roll back to previously visited concept when the student’s exploration had lead to a next concept that did not offer any outgoing hyperlinks for further exploration or if all outgoing hyperlinks had been already traversed once earlier during this same exploration.

In contrast with practice used often elsewhere in this publication, in Appendix N as well as in Table 9.1 and Table 9.2 if ranking is based on shared ranking positions we have decided to give to all representatives of this shared position the same ranking value which is a ranking value that would have been used next if there were not need for sharing the position (i.e. we now avoid using an average of all ranking values that would have been used if there were not need for sharing the position and skipping corresponding number of ranking values). We decided to use all ranking values even in case of shared ranking so that our analysis about overlap of listing of corresponding highest-ranking core relationships and highest-ranking traversed hyperlinks discussed in Chapter 9 could become more intuitive.

Conceptual network of concept maps drawn by students			Hyperlink network of the Wikipedia		
<i>Core relationships (i.e. relationships between 102 core concepts extended with concept "brother" that are mentioned by at least two students in concept maps drawn by students) shown so that each concept is transformed to the closest matching entry of Wikipedia article (relationships of concept maps do not have any specified linking direction, each pair of concepts are shown in alphabetical order) (n=103)</i>	<i>Number of occurrences so that at most one occurrence counted for each student</i>	<i>Ranking</i>	<i>Traversed hyperlinks of the Wikipedia in exploration paths of students (n=49)</i>	<i>Number of occurrences so that at most one occurrence counted for each student</i>	<i>Ranking</i>
Family=Friendship	15	1	Happiness -> Emotion	29	1
* Birth=Death	13	2s	* Emotion -> Love	26	2
* Family=Love	13	2s	Joy -> Happiness	24	3s
Friendship=School	10	3	* Disease -> Death	24	3s
* Family=Home	9	4s	Happiness -> Joy	21	4
School=Work	9	4s	Human -> Diet (nutrition)	19 (2)	5s
* Animal=Nature	8	5s	Emotion -> Experience	19	5s
* Friendship=Love	8	5s	Experience -> Emotion (only to roll back)	18	6
* Child=Family	7	6s	Organism -> Biology	17	7s
Death=Living	7	6s	Adolescence -> Education	17	7s
* Family=Father	7	6s	* Love -> Friendship	16	8
Family=Living	7	6s	Education -> Learning	14	9s
Joy=Sorrow	7	6s	Learning -> Education	14	9s
* Family=Mother	6	7s	Emotion -> Happiness	14	9s
* Father=Mother	6	7s	* Family -> Mother	13	10s
Food=Water	6	7s	Diet (nutrition) -> Health	13	10s
Friendship=Hobby	6	7s	* Health -> Disease	13	10s
Money=Work	6	7s	* Love -> Happiness	11	11s
Birth=Living	5	8s	Emotion -> Joy	11	11s
Education=Work	5	8s	* Love -> Emotion	10	12s
Living=Nature	5	8s	* Friendship -> Adolescence	10	12s
* Nature=Plant	5	8s	* Biology -> Nature	9	13s
* Plant=Tree	5	8s	Organism -> Plant	9	13s
Study=Work	5	8s	* Oxygen -> Water	9	13s
Animal=Dog	4	9s	Human -> Adolescence	9 (2)	13s
Atmosphere of Earth=Water	4	9s	* Human -> Family	9 (6)	13s
Cat=Dog	4	9s	Human -> Emotion	9 (3)	13s
Computer=Television	4	9s	Adolescence -> Child	9	13s
* Death=Disease	4	9s	Sun -> Plant	8	14s
Death=Health	4	9s	Organism -> Heart	8	14s
Family=Happiness	4	9s	Human -> Health	8 (3)	14s
* Family=Human	4	9s	Experience -> Learning (only to roll back)	8	14s
Friendship=Happiness	4	9s	* Death -> Disease	8	14s
Friendship=Human	4	9s	* Death -> War	8	14s
Friendship=Joy	4	9s	Learning -> Experience	8	14s
Home=Living	4	9s	* Love -> Family	8	14s
Human=Living	4	9s	War -> Peace	8	14s
* Human=Love	4	9s	Mother -> Parent	8	14s
* Human=Nature	4	9s	Biology -> Organism	7	15s
Living=Work	4	9s	Biology -> Animal	7	15s
Nature=Water	4	9s	Oxygen -> Plant	7	15s
Animal=Family	3	10s	Joy -> Emotion (only to roll back)	7	15s
Animal=Food	3	10s	* Plant -> Tree	7	15s
* Animal=Human	3	10s	* Sea -> Water	7	15s
* Biology=Nature	3	10s	* Family -> Sibling	7	15s
Birth=Health	3	10s	Sibling -> Love	7	15s
* Death=Human	3	10s	* Water -> Sea	7	15s
* Death=Old_age	3	10s	Sun -> Oxygen	6	16s
Death=Sorrow	3	10s	* Animal -> Human	6	16s
* Death=War	3	10s	* Animal -> Nature	6	16s
Dog=Family	3	10s	Human -> Happiness	6 (5)	16s
Dog=Pet	3	10s	* Plant -> Nature	6	16s
* Education=School	3	10s	Plant -> Light	6	16s
Family=House	3	10s	* School -> Education	6	16s

Family=Joy	3	10s	* Education -> School	6	16s
Family=Work	3	10s	Education -> Adolescence	6	16s
* Food=Health	3	10s	Education -> Leisure	6	16s
Food=Living	3	10s	Death -> Organism	6	16s
Friendship=Party	3	10s	* Death -> Human	6	16s
Ground=Water	3	10s	* Child -> Family	6	16s
* Happiness=Love	3	10s	Teacher -> Learning	6	16s
Hobby=Leisure	3	10s	* Family -> Child	6	16s
Hobby=School	3	10s	Peace -> Education	6	16s
* Home=House	3	10s	Diet_(nutrition) -> Organism	6	16s
Home=School	3	10s	Heart -> Organism (only to roll back)	6	16s
Home=Work	3	10s	* Mother -> Love	6	16s
Living=Religion	3	10s	Biology -> Human	5	17s
Living=School	3	10s	Human -> War	5 (3)	17s
Living=Water	3	10s	God -> Father	5	17s
* Nature=Sun	3	10s	Education -> Human	5	17s
School=Study	3	10s	Education -> Teacher	5	17s
* Adolescence=Friendship	2	11s	Death -> Heart	5	17s
Animal=Environment	2	11s	Child -> Adolescence	5	17s
Animal=God	2	11s	* Teacher -> School	5	17s
Animal=Tree	2	11s	Tree -> Oxygen	5	17s
Atmosphere_of_Earth=Ground	2	11s	Love -> Biology	5	17s
Automobile=Family	2	11s	Heart -> Death (only to roll back)	5	17s
Automobile=House	2	11s	Health -> Biology	5	17s
Birth=Child	2	11s	Work -> Leisure (only to roll back)	5	17s
Birth=Family	2	11s	Religion -> God	5	17s
Birth=Growing	2	11s	Light -> Sun	5	17s
Birth=Human	2	11s	Parent -> Human	5	17s
Birth=Nature	2	11s	Parent -> Birth	5	17s
Book=School	2	11s	Leisure -> Work	5	17s
Chair=House	2	11s	Animal -> Organism	4	18s
Child=Hospital	2	11s	Father -> Love	4	18s
Child=Human	2	11s	* School -> Teacher	4	18s
Clock=Computer	2	11s	Child -> Parent	4	18s
Clock=School	2	11s	* Nature -> Animal	4	18s
Clothing=Shoe	2	11s	* Nature -> Human	4	18s
Computer=Leisure	2	11s	Adolescence -> Old_age	4	18s
Death=Nature	2	11s	* Happiness -> Love	4	18s
Diet_(nutrition)=Water	2	11s	* Family -> Father	4	18s
* Disease=Health	2	11s	Family -> Leisure	4	18s
Dream=Health	2	11s	War -> Religion	4	18s
Education=Living	2	11s	Health -> Diet_(nutrition)	4	18s
* Emotion=Love	2	11s	Leisure -> Family	4	18s
Environment=Family	2	11s	Water -> Sun	4	18s
Environment=Nature	2	11s	Oxygen -> Sun	3	19s
Experience=Work	2	11s	Oxygen -> Disease	3	19s
Family=Health	2	11s	* Human -> Love	3 (2)	19s
Family=Hobby	2	11s	Human -> Religion	3 (0)	19s
Family=Money	2	11s	Human -> Clothing	3 (2)	19s
Family=Pet	2	11s	* Father -> Family	3	19s
* Family=Sibling	2	11s	Plant -> Organism	3	19s
Family=Study	2	11s	Plant -> Water	3	19s
Family=Telephone	2	11s	* Nature -> Sun	3	19s
Father=Home	2	11s	Nature -> Organism	3	19s
Food=Television	2	11s	Nature -> Oxygen	3	19s
Friendship=Leisure	2	11s	* Nature -> Plant	3	19s
Friendship=Living	2	11s	Travel -> Water	3	19s
Friendship=Pet	2	11s	Adolescence -> Television	3	19s
Friendship=Sibling	2	11s	Learning -> Teacher (only to roll back)	3	19s
Friendship=Study	2	11s	Diet_(nutrition) -> Death	3	19s
Friendship=Work	2	11s	Sibling -> Parent	3	19s
God=Organism	2	11s	War -> Disease	3	19s
Ground=Nature	2	11s	Birth -> Animal	3	19s
Health=Light	2	11s	Television -> Adolescence (only to roll back)	3	19s

Health=Old_age	2	11s	Religion -> Human	3	19s
Health=Physical_fitness	2	11s	* Old_age -> Death	3	19s
Heart=Love	2	11s	* Water -> Oxygen	3	19s
Hobby=Work	2	11s	Water -> Plant	3	19s
Holiday=Party	2	11s	Water -> Travel	3	19s
Holiday=Work	2	11s	Automobile -> Oxygen	2	20s
Home=Mother	2	11s	Biology -> Plant	2	20s
House=Work	2	11s	Biology -> Health	2	20s
Joy=Living	2	11s	Oxygen -> Automobile	2	20s
Joy=Love	2	11s	Oxygen -> Heart	2	20s
Learning=Love	2	11s	Human -> Oxygen	2 (1)	20s
* Leisure=Television	2	11s	Human -> House	2 (1)	20s
Living=Music	2	11s	Father -> Parent	2	20s
Living=Organism	2	11s	* Father -> Mother	2	20s
Living=Peace	2	11s	Plant -> Biology	2	20s
Living=Purpose	2	11s	Plant -> Animal	2	20s
Living=Sorrow	2	11s	Plant -> Oxygen	2	20s
Living=Sun	2	11s	* Home -> Family	2	20s
Living=Travel	2	11s	Education -> Biology	2	20s
* Love=Mother	2	11s	Death -> Oxygen	2	20s
Love=Nature	2	11s	Tree -> Water	2	20s
Love=Parent	2	11s	Peace -> War	2	20s
Nature=Tree	2	11s	* Sibling -> Family	2	20s
* Oxygen=Water	2	11s	* House -> Home	2	20s
* School=Teacher	2	11s	Religion -> Sun	2	20s
* Sea=Water	2	11s	Clothing -> Religion	2	20s
Summer=Sun	2	11s	Light -> Television	2	20s
			Parent -> Father	2	20s
			Parent -> Child	2	20s
			Parent -> Sibling	2	20s
			Leisure -> Education	2	20s
			Leisure -> Sibling	2	20s
			Water -> Biology	2	20s
			Friendship -> Animal	2	20s
			* Friendship -> Love	2	20s
			* Mother -> Father	2	20s
			Animal -> Oxygen	1	21s
			Animal -> Water	1	21s
			* Human -> Animal	1 (0)	21s
			Human -> Music	1 (1)	21s
			Father -> Sibling	1	21s
			Education -> Sibling	1	21s
			Child -> Old_age	1	21s
			Child -> Leisure	1	21s
			Teacher -> Education	1	21s
			Diet_(nutrition) -> Religion	1	21s
			Food -> Human	1	21s
			Disease -> Oxygen (only to roll back)	1	21s
			* Birth -> Death	1	21s
			Birth -> Mother	1	21s
			Television -> Clothing (only to roll back)	1	21s
			Television -> Light (only to roll back)	1	21s
			* Television -> Leisure (only to roll back)	1	21s
			* Health -> Food	1	21s
			Clothing -> Television	1	21s
			Parent -> Mother	1	21s
			Old_age -> Adolescence	1	21s
			* Leisure -> Television	1	21s
			Water -> Human	1	21s
			* Mother -> Family	1	21s

Appendix O

These listings shows three key vocabularies, containing only nouns, generated for preliminary testing of proposed method of publication [P6] performed based on simple learning scenarios about children aiming to adopt basic vocabulary used in everyday life. In all key vocabularies the ranking values for each noun indicates its position among all highest-ranking nouns and thus words other than nouns are not considered.

The key vocabularies of learner's knowledge and learning objective consisted of the highest-ranking 10 percent of the nouns in text samples provided by the learner and the Wikipedia article respectively about selected topics. In listings shown here key vocabulary of learner's knowledge is based on the highest-ranking nouns occurring in a text sample generated by a test user in May 2010 about topic "child" and key vocabulary of learning objective is based on high-frequency words of Wikipedia article "Child" (relying on Wikipedia article version on 20 May 2010).

The key vocabulary of learning context consisted of 100 highest-ranking nouns used by English speaking children queried from Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) for combination of early educational levels denoted by "Rec/Prep/K" that we will refer to as school level Preparatory (<http://www.oxfordwordlist.com/pages/search.asp>). Thus when querying the key vocabulary of learning context the following settings were used: school year was "Rec/Prep/K" and language was "English speaking" and for other settings concerning gender, indigeneous, school setting, location and text type an option "any" was used.

In the Wikipedia both entry Sister and entry Brother are redirected to shared article Sibling and thus in the Wikipedia word "sibling" can be considered to represent both words "brother" and "sister". Thus in key vocabularies of learner's knowledge and learning context words "brother" and "sister" have a shared corresponding Wikipedia article Sibling, indicated with an asterisk (*) in listings below. It was considered that in key vocabulary of learning objective words "criminal" and "imprisonment" cover related themes and thus "imprisonment" was combined with "criminal" and thus they have a shared corresponding Wikipedia article Crime, indicated with a double asterisk (**) in listings below.

When generating key vocabulary of learning context based on highest-ranking nouns of Oxford Wordlist numerals were excluded (in contrast with key vocabulary of learning objective) and word "fun", that would have been positioned in ranking listing between "day" and "play", was excluded (in contrast with the emergence of concept Fun in other analysis, for example among core concepts, see Appendix F) and word "can" was included as a noun form although we assume that "can" has gained its high-ranking position in Oxford Wordlist due to its verb form. Sequences of words in alphabetical and non-alphabetical order in Oxford Wordlist ((Lo Bianco et al. 2008); (Bayetto 2010)) (<http://www.oxfordwordlist.com/pages/search.asp>) made us to suggest that perhaps some of the ranking values should be considered as shared ranking values. It remained as an open question if some of ranking values of Oxford Wordlist (in column indicated with a triple asterisk (***) in listing below) should be shared and finally we decided to give individual ranking value that increase one by one to all words in our listing of key vocabulary of learning context (i.e. no shared ranking values were used).

Key vocabulary of learner's knowledge			Key vocabulary of learning objective			Key vocabulary of learning context		
Concept	The closest matching entry of Wikipedia article	Ranking	Concept	The closest matching entry of Wikipedia article	Ranking	Concept	The closest matching entry of Wikipedia article	Ranking***
girl	Girl	1	child	Child	1	weekend	Weekend	1
boy	Boy	2	age	Age	2	dad	Father	2
school	School	3	country	Country	3	home	Home	3
kindergarten	Kindergarten	4	attitude	Attitude	4shared	house	House	4
protection	Protection	5	time	Time	4shared	mum	Mother	5
laugh	Laughter	6	group	Group	5shared	time	Time	6
cry	Cry	7	marriage	Marriage	5shared	day	Day	7
worry	Worry (emotion)	8	year	Year	5shared	play	Play_(disambiguation)	8
joy	Joy	9	action	Action	6shared	park	Park	9
color	Color	10	adhd	Attention_deficit_hyperactivity_disorder	6shared	birthday	Birthday	10
ball	Ball	11	criminal**	Crime**	6shared	Saturday	Saturday	11
sandbox	Sandbox	12	education	Education	6shared	party	Party	12
game	Game	13	human	Human	6shared	Sunday	Sunday	13
square	Square	14	imprisonment**	Imprisonment**	(imprisonment combined with criminal, thus shared corresponding Wikipedia article Crime)	dog	Dog	14
backpack	Backpack	15	law	Law	6shared	brother*	Sibling*	15
		16	learning	Learning	6shared	football	Football	16
baby	Infant	17	majority	Majority	6shared	friends	Friendship	17
home	Home	18	play	Play (disambiguation)	6shared	can	Can	18
father	Father	19	seven	7 (number)	6shared	love	Love	19
mother	Mother	20	skill	Skill	6shared	zoo	Zoo	20
sister*	Sibling*	21	stage	Stage	6shared	school	School	21
brother*	Sibling*	(already above)	way	Way	6shared	playing	Play_(activity)	22
			world	World	6shared	night	Night	23
						bed	Bed	24
						shop	Shop	25
						bike	Bike	26
						dinner	Dinner	27
						car	Automobile	28
						fish	Fish	29
						beach	Beach	30
						sister*	Sibling*	(already above)
						name	Name	31
						people	People	32
						movies	Film	33
						water	Water	34
						book	Book	35
						Friday	Friday	36
						toy	Toy	37
						shark	Shark	38
						family	Family	39
						playground	Playground	40
						tv	Television	41
						buddy	Buddy	42
						cat	Cat	43

						lunch	Luncheon	44
						yesterday	Yesterday	45
						girl	Girl	46
						icecream	Ice_cream	47
						swimming	Swimming	48
						baby	Infant	49
						holidays	Holiday	50
						ride	Ride	51
						dinosaur	Dinosaur	52
						game	Game	53
						present	Present	54
						slide	Slide	55
						ball	Ball	56
						shopping	Shopping	57
						chips	Chip_(disambiguation)	58
						food	Food	59
						work	Work	60
						footy	Footy	61
						magic	Magic	62
						mermaid	Mermaid	63
						rabbit	Rabbit	64
						soccer	Association_football	65
						dragon	Dragon	66
						fairy	Fairy	67
						hair	Hair	68
						boat	Boat	69
						cousin	Cousin	70
						jungle	Jungle	71
						riding	Riding	72
						zebra	Zebra	73
						animals	Animal	74
						cake	Cake	75
						castle	Castle	76
						chocolate	Chocolate	77
						horse	Horse	78
						Monday	Monday	79
						morning	Morning	80
						pool	Pool	81
						room	Room	82
						sea	Sea	83
						sleepover	Sleepover	84
						today	Today	85
						breakfast	Breakfast	86
						garden	Garden	87
						monkey	Monkey	88
						monster	Monster	89
						outside	Outside	90
						show	Show	91
						week	Week	92
						computer	Computer	93
						inside	Inside	94
						lion	Lion	95
						parade	Parade	96
						pirate	Piracy	97
						snake	Snake	98
						tiger	Tiger	99

Appendix P

Listing that shows the highest-ranking words (only common nouns) gathered in our experiment from teenaged students (n=103) when they were asked to list and rank most significant vocabulary concerning topic “life”. This listing shows high-frequency words with ranking based on occurrences in word lists of 20 words generated by students (each student could mention each concept at most once in her word list).

Following rule was used when generating this listing: for each concept at most one occurrence is counted per student, and if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position (notation suffix -s indicates shared ranking position).

Notation containing slash symbol (/) separating two concepts is used when a word gathered from students was considered to have more than one possible dominating form of interpretation or translation. Although excluded from the list below since not qualified as suitable common nouns, students mentioned in their word lists two specific languages, including 7 occurrences for Finnish and 1 occurrence for German.

Ranking	Concept in English	Concept in Finnish	Occurrences
1	family	perhe	53
2	friend	ystävä	49
3	work	työ	41
4	death	kuolema	40
5.5s	love; school	rakkaus; koulu	33
7.5s	food; water	ruoka; vesi	31
9	animal	eläin	29
10	human	ihminen	24
11	birth	syntymä	23
12	nature	luonto	21
13	home	koti	18
15s	child; joy; sun	lapsi; ilo; aurinko	16
18s	dog; hobby; house	koira; harrastus; talo	15
22s	education; health; money; sorrow; study	koulutus; terveys; raha; suru; opiskelu	14
25	computer	tietokone	13
26	plant	kasvi	12
28s	car; happiness; tree	auto; onnellisuus; puu	11
30.5s	book; cat	kirja; kissa	10
34.5s	air; clock; learning; mother; summer; television	ilma; kello; oppiminen; äiti; kesä; televisio	9
39.5s	living; music; party; religion	eläminen; musiikki; juhla; uskonto	8
46.5s	city; cloth; elderness; environment; father; freetime; holiday; light; pet; world	kaupunki; vaate; vanhuus; ympäristö; isä; vapaa-aika; loma; valo; lemmikki; maailma	7
58s	childhood; disease; emotion; experience; fun; ground/Earth; growing; hate; heart; paper; sea; shoe; sport	lapsuus; sairaus; tunne; kokemus; hupi; maa; kasvaminen; viha; sydän; paperi; meri; kenkä; urheilu	6
71.5s	baby; biology; eating; flower; forest; god; goodness; peace; pen/pencil; philosophy; purpose; succeeding; war; young (person)	vauva; biologia; syöminen; kukka; metsä; jumala; hyvyys; rauha; kynä; filosofia; tarkoitus; onnistuminen; sota; nuori	5
90.5s	bed; bread; chair; dream_(sleeping); pleasure; evolution; exam; future; goal_(to_achieve); hospital; marriage; nutriment; organism; oxygen; parent; people; phone; physical_training; rain; sadness; sister; teacher; time; travel	sänky; leipä; tuoli; uni; nautinto; evoluutio; koe; tulevaisuus; tavoite; sairaala; avioliitto; ravinto; eliö; happi; vanhempi; ihminen_(ryhmä); puhelin; liikunta; sade; surullisuus; sisko; opettaja; aika; matka	4
128s	adulthood; art; bird; blood; breath; breathing; brother; career; cell; culture; dance; dating; difference; disappointment; dna; dream_(wishing); drink; earth; economy; fire; freedom; gift; greenness; hardness; ice_cream; laugh; leaf/newspaper; learning_content; life_cycle; lifestyle; luck; moral; notebook; pain; problem; relationship; relative; reproduction; science; sky/heaven; smallness; sociality; spirit; suffering; travelling; weather; wheel/bicycle; wife; working_place; year; youth	aikuisuus; taide; lintu; veri; hengitys; hengitys; veli; ura; solu; kulttuuri; tanssi; seurustelu; erilaisuus; pettymys; dna; unelma; juoma; maapallo; talous; tuli; vapaus; lahja; vihreys; kovuus; jäätelö; nauru; lehti; oppi; elämänkaari; elämäntapa; onni; moraali; vihko; tuska; ongelma; suhde; sukulainen; lisääntyminen; tiede; taivas; pienuus; sosiaalisuus; henki; kärsimys; matkustaminen; sää; pyörä; vaimo; työpaikka; vuosi; nuoruus	3
198s	accessory; achievement; adult; age; apartment; autumn; ball; beach; bear; beer; being; being_alive;	varuste; saavutus; aikuinen; ikä; asunto; syksy; pallo; ranta; karhu; olut; oleminen;	2

	<p>belief; bigness; boy; boyfriend; brain; butter; change; closeness; confirmation_school_(religion); dad; day; difficulty; elder; electricity; end; enjoying; evilness; eyeglasses; foreign_country; friendship; girl; history; honey; horse; identity; importance; information; internet; justice; lamp; law; loneliness; loveliness; match_(for firing); material; meaning; mobile_phone; motorcycle; moving; niceness; night; old; outer_space; park; performance; person; planet; possibility; prison; roof; rose; senior_house; sense; separation/divorce; sex; shirt; shop; sibling; smile; song; spring; stress; success; sunlight; table; tax; tobacco; transition; trap; trousers; universe; versatility; victory; wedding; wish; wolf; yard_(garden)</p>	<p>elossaoleminen; uskomus; suuruus; poika; poikaystävä; aivot; voi; muutos; läheisyys; rippikoulu; isä; päivä; vaikeus; vanhus; sähkö; loppu; nauttiminen; pahuus; silmälasit; ulkoma; ystävyys; tyttö; historia; hunaja; hevonen; identiteetti; tärkeys; tieto; internet; oikeus; lamppu; laki; yksinäisyys; ihanuus; tulitikku; aine; merkitys; kännykkä; moottoripyörä; liikkuminen; somuus; yö; vanha; ulkoavaruus; puisto; suoritus; henkilö; planeetta; mahdollisuus; vankila; katto; ruusu; vanhainkoti; aisti; ero; seksi; paita; kauppa; sisarus; hymy; laulu; kevät; stressi; menestys; auringonvalo; pöytä; vero; tupakka; siirtymä; ansa; housut; maailmankaikkeus; monipuolisuus; voitto; häät; toive; susi; piha</p>	
432s	<p>accident; activity; admiration; adolescence; adrenaline; adventure; adversity; agreement; angel; anger; animal_kingdom; arc; assignment; atom; attitude; awesomeness; baptism_ceremony; bacteria; badness; bag; balance; bank_(money); bar_(restaurant); basket_ball; beauty; beginning; behavior; being_(person/animal); being_together; belonging; bill_(payment); biodiversity; biologist; birch; birthday; body; body-training; bond_(economics); bow_tie; bug; building; bush; calmness; camp; candle; candy; care; carrot; catastrophe; cave; cell_phone; challenge; cheese; chicken; christmas; church; cider; circulation_(rotation); class; climax; climbing; closet; costume; cloud; coal; coffee; coffee_cup; coffin; colonization; color; combat; community; competition; complicatedness; confidence; conscience; consumer; convenience; cottage; countryside; couple; course; criminal; cross_(symbol); cruelty; darkness; dead; death_penalty; decomposer; defeat; degree_(diploma); depressiveness; development; diagnose; dirtiness; disc; diversity; doctor_(physician); drinking; driving_licence; duck; duty; easy; easiness; ecosystem; effort; electronics; energy; engagement_(prior_wedding); entertainment; eraser; eternity; event; expedition; exploration; fail; family_(relatives); farm_(farmhouse); fashion; fastness; scare; scariness; feeling; fence; film; fishery; flame; flute; flying; fog; football; forty-two; freedom_of_speech; fruit; fulfillment; funeral; funniness; fur; futility; game; gender; gene; getting_along; getting_dumber; getting_things_done; getting_wiser; ghost; giraffe; girlfriend; glacier; globalization; godship; golf; government; grandmother; grass_(lawn); greatness; guess; guitar; habit; hair; hairspray; ham; handsomeness; hatred; having_fun; head; heaven; hecticness; hedgehog; helping; heredity; heritage; home_country; homework; honesty; hope; hotness; household_work; human_relationship; hurting; ideology; injustice; ink; interactivity; item; joke; kindergarten; kindness; knowing; knowledge; lake; laptop; lawn; leaf_of_lettuce; life-givingness; lifetime; lighter_(for_firing); limitedness; living_region; living_room; long_time; longing; longness; loss; loudspeaker; lungs; machine; mad; magic; mammal; man; mandatoriness; marine_life; market_(economics); massacre; meat; medicine_(discipline); medicine_(healing_chemical); memory; mental_development; middle-ageness; milk; mind; minister_(politics); minute; miracle; misery; misfortune; molecule; moment; moon; mountain; mouse; movie; moving_(changing_location_of_home); mp3_player; nailpolish; naturalness; need; neighbor; nightclub; noise; normality; ocean; organ; organs_(entity); outlook; passing_time; passion; past; patriotism; pelvis; pencil_case; pension; period; personality; phoenix; photosynthesis; physicality; physics; plane; play_age; playing_(sports/game); politics; pool_(small_lake); potential; predator; pregnancy; president; prey; privacy; producer; property;</p>	<p>onnettomuus; toiminta; ihailu; nuoruus; adrenaliini; seikkailu; vastoinikäminen; sopimus; enkeli; vihaisuus; eläinkunta; kaari; tehtävä; atomi; asenne; hurjuus; kastejuhla; bakteeri; huonous; laukku; tasapaino; pankki; baari; koripallo; kauneus; alku; käytös; olento; yhdessäolo; kuuluvuus; lasku; luonnon_monimuotoisuus; biologi; koivu; syntymäpäivä; ruumis; kehonrakennus; joukkovelkakirja; rusetti; ötökkä; rakennus; pensas; rauhallisuus; leiri; kynttilä; makeinen; hoito; porkkana; katastrofi; luola; matkapuhelin; haaste; juusto; kana; joulujoulu; kirkko; siideri; kiertokulku; luokka; huippukohta; kiipeäminen; kaappi; asu; pilvi; hiili; kahvi; kahvikuppi; arkku; löytöretkeily; väri; kamppailu; yhteisö; kilpailu; mutkikkaus; tyytyväisyys; omatunto; kuluttaja; mukavuus; mökki; maaseutu; pari/pariskunta; kurssi; rikollinen; risti; julmuus; pimeys; kuollut; kuolemanrangaistus; hajottaja; häviö; tutkinto; masentavuus; kehitys; diagnoosi; likaisuus; kiekko; monimuotoisuus; lääkäri; juominen; ajokortti; ankka; velvollisuus; helppo; helppous; ekosysteemi; ponnistelu; elektroniikka; energia; kihlat; viihde; kumi; ikuisuus; tapahtuma; tutkimusmatka; tutkiminen; epäonnistuminen; suku; maatalo; muoti; nopeus; pelko; pelottavuus; tuntemus; aita; filmi; kalastusyhtiö; liekki; huilu; lentäminen; sumu; jalkapallo; neljäkymmentäkaksi; sananvapaus; hedelmä; täyttymys; hautajaiset; huvittavuus; turkki; turhuus; peli; sukupuoli; geeni; viihtyvyys; tyhmistyminen; aikaansaavuus; viisastuminen; haamu; kirahvi; tyttöystävä; jäätiikkö; globalisoituminen; palvonta; golf; eduskunta; isoäiti; ruoho; suurenmoisuus; veikkaus; kitara; tapa; hiukset; hiuslakka; kinkku; komeus; vihaisuus; hauskanpito; pää; taivas; hektisyys; siili; auttaminen; perinnöllisyys; perintö; kotimaa; läksyt; rehellisyys; toivo; kuumuus; kotitalous; ihmissuhde; sattuminen_(kipu); ideologia; epäoikeudenmukaisuus; muste; vuorovaikutteisuus; kappale; vitsi; tarha; ystävällisyys; tietäminen; tietämys; järvi; kannettava; nurmikko; salaatinlehti; elämän_mahdollistaminen; elinaika; sytytin; rajallisuus; asuinpaikka; olohuone; pitkä_aika; kaipaaminen; pituus; menetyks; kaiutin; keuhkot; kone; mieli; mieluinen; taika; nisäkäs; mies/ihminen; pakollisuus; merellinen_elämä; markkinat; joukkotuho; liha; lääketiede; lääke; muisto; henkinen_kehitys; keski-ikäisyys; maito; mieltä; ministeri; minuutti; ihme; kurjuus; epäonni; molekyyli; hetki; kuu; vuori; hiiri; elokuva; muutto; mp3-soitin; kynsilakka; luonnollisuus; tarve; naapuri; yökerho; melu; tavallisuus; valtameri; elin; elimistö; katsomus; ajan_viettäminen; intohimo; menneisyys; isänmaanrakkaus;</p>	1

	<p>property_(belongings); question; reading; realisticness; reason; record_(new_achievement); rectangle; regeneration; relaxing; residing; respect; responsibility; rna; road; robot; rock_'n_roll; rock_(ground_material); room_(in_apartment); satisfaction; school_institution; sealife; senate; sharpener_(for_pencils); shelf; shelter; shine; shortness; shower; sign; silence; singing; single-home_house; ice skate; skateboard; skill; sky; sleeping; slowness; snow; snowboard; social_life; sock; sofa; soul; space; spirituality; spoon; spouse; square; star; start; stock_(economics); strangeness; string_(of_clothing); string_of_life; study book; style; suicide; sunshine; surfboard; survival; surviving; survivor; suspense; swimming; talent; target_of_attention; teaching; teaching_children; technology; teen; tennis; thing; thinking; thought; tiger; tradition; trip; ugliness; undersea; understanding; uneven; unfairness; uniqueness; value; variation; videogame_device; view_(opinion); vitamin; vocation; volleyball; volcano; walking; wall_(of_room); warmth; weekday; weirdness; well-being; window; winter; woman; wonderfulness; worry; writing; zebra</p>	<p>lonkka; penaali; eläke; valhe; persoona; feeniks; fotosynteesi; fyysisuus; fysiikka; lentokone; leikki-ikä; pelaaminen; politiikka; lampi; valmius; peto; raskaus; presidentti; saalis; yksityisyys; tuottaja; omaisuus; omaisuus; kysymys; lukeminen; todenmukaisuus; syy; ennätys; ruutu; uusiutuminen_(regeneraatio); rentoutuminen; asuminen; kunnioittaminen; vastuuntunto; rna; tie; robotti; rock_'n_roll; kallio; huone; työdytys; koululaitos; merielämä; hallitus; teroitin; hylly; suoja; paiste; lyhyys; suihku; merkki; hiljaisuus; laulaminen; omakotitalo; luistin; skeittilauta; taito; taivas; nukkuminen; hitaus; lumi; lumilauta; sosiaalinen_elämä; sukka; sohva; sielu; avaruus/tila; hengellisyys; lusikka; puoliso; neliö; tähti; alku; osake; outous; lanka; elämänlanka; oppikirja; tyyli; itsemurha; auringonpaiste; surffilauta; selviytyminen; selviytyminen; selviytyjä; jännitys; uiminen; kyky; mielenkiinnon_kohde; opetus; lastenkasvatus; teknologia; teini; tennis; asia/esine; ajattelu; ajatus; tiikeri; perinne; retki; rumuus; merenalainen; ymmärtäminen; epätasaisuus; väärä; ainutlaatuisuus; arvo; vaihtelevuus; videopelilaitte; näkemys; vitamiini; kutsumus; lentopallo; tulivuori; käveleminen; seinä; lämpö; arki; omituisuus; hyvinvointi; ikkuna; talvi; nainen; suurenmoisuus; huoli; kirjoittaminen; seepra</p>	
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Appendix Q

This list shows the high-frequency words (only common nouns) gathered in our experiment from teenaged students (n=103) when they were asked to list and rank most significant vocabulary concerning topic “life”. This list shows high-frequency words with ranking based on sum of “measures of importance” originating from ranking given by each student for the words she generated to form her word list of 20 words (ranking values of “measure of importance” originally given by students in ascending range from 1 to 20 were translated to an inverse descending range of measures of importance from 21 to 1, thus greater value now indicating more important).

Following rule was used when generating the list: for each concept we counted together all “measure of importance” values, and if concepts share same frequency value and thus same ranking position these concepts get an average of consecutive ranking values that they would have gotten if not sharing the same ranking position (notation suffix -s indicates shared ranking position).

Notation containing slash symbol (/) separating two concepts is used when a word gathered from students was considered to have more than one possible dominating form of interpretation or translation. Although excluded from the list below since not qualified as suitable common nouns, for two specific languages students mentioned in their word lists sum of measures of importance for Finnish was 76 (corresponding to about ranking 50.5s) and for German 3 (corresponding about ranking 541s).

<i>Ranking</i>	<i>Concept in English</i>	<i>Concept in Finnish</i>	<i>Sum of measures of importance</i>
1	family	perhe	903
2	friend	ystävä	821
3	love	rakkaus	525
4	work	työ	445
5	water	vesi	408
6	food	ruoka	396
7	death	kuolema	363
8	school	koulu	362
9	human	ihminen	335
10	birth	syntymä	321
11	nature	luonto	303
12	animal	eläin	285
13	home	koti	237
14	health	terveys	225
15	sun	aurinko	224
16	child	lapsi	202
17	joy	ilo	195
18	hobby	harrastus	188
19	study	opiskelu	186
20	happiness	onnellisuus	179
21	education	koulutus	172
22	house	talo	147
23	plant	kasvi	136
24	mother	äiti	133
25	money	raha	130
26	air	ilma	121
27	dog	koira	118
28	world	maailma	106
29.5s	father; living	isä; eläminen	105
31	sorrow	suru	104
32	learning	oppiminen	103
33.5s	book; computer	kirja; tietokone	99
35	clock	kello	98
36	cloth	vaate	95
38s	freetime; holiday; music	vapaa-aika; loma; musiikki	91
40	party	juhla	87
41	emotion	tunne	86

43s	fun; summer; tree	hupi; kesä; puu	85
45.5s	purpose; television	tarkoitus; televisio	84
47.5s	car; heart	auto; sydän	80
49	oxygen	happi	79
50.5s	childhood; parent	lapsuus; vanhempi	76
52	environment	ympäristö	75
53	ground/Earth	maa	74
54	baby	vauva	73
55	growing	kasvaminen	72
56	peace	rauha	71
57	goodness	hyvyys	70
58	eating	syöminen	69
59.5s	light; travel	valo; matka	67
61	experience	kokemus	66
63s	goal (to achieve); pet; succeeding	tavoite; lemmikki; onnistuminen	64
65.5s	religion; sport	uskonto; urheilu	62
67	nutriment	ravinto	61
68	elderness	vanhuus	60
70s	cat; forest; god	kissa; metsä; jumala	59
72	future	tulevaisuus	58
73	brother	veli	56
74	time	aika	55
75.5s	luck; physical_training	onni; liikunta	54
77	dream (sleeping)	uni	53
79.5s	city; pleasure; philosophy; shoe	kaupunki; nautinto; filosofia; kenkä	52
82.5s	learning_content; marriage	oppi; avioliitto	51
84	bread	leipä	49
85	sea	meri	48
87.5s	difference; dream (wishing); flower; phone	erilaisuus; unelma; kukka; puhelin	47
90	dance	tanssi	46
91.5s	moral; working_place	moraali; työpaikka	45
94.5s	bed; biology; blood; reproduction	sänky; biologia; veri; lisääntyminen	44
97	breathing	hengitys	42
98.5s	organism; people	eliö; ihminen (ryhmä)	41
100	person	henkilö	40
102s	boyfriend; cell; gift	poikaystävä; solu; lahja	39
104.5s	hospital; sociality	sairaala; sosiaalisuus	38
107s	evolution; possibility; travelling	evoluutio; mahdollisuus; matkustaminen	37
109.5s	greenness; victory	vihreys; voitto	36
115s	career; closeness; drink; horse; laugh; relationship; science; spirit; universe	ura; läheisyys; juoma; hevonen; nauru; suhde; tiede; henki; maailmankaikkeus	35
121.5s	art; pain; rain; teacher	taide; tuska; sade; opettaja	34
126.5s	adulthood; butter; identity; pen/pencil; versatility; wedding	aikuisuus; voi; identiteetti; kynä; monipuolisuus; häät	33
133.5s	adult; justice; paper; sadness; sense; sibling; sister; suffering	aikuinen; oikeus; paperi; surullisuus; aisti; sisarus; sisko; kärsimys	32
139.5s	brain; freedom; relative; senior_house	aivot; vapaus; sukulainen; vanhainkoti	31
144.5s	exam; hate; importance; wheel/bicycle; year; young (person)	koe; viha; tärkeys; pyörä; vuosi; nuori	30
148	dna	dna	29
150s	disease; dissatisfaction; trousers	sairaus; pettymys; housut	28
153s	moving; war; wife	liikkuminen; sota; vaimo	27
158s	autumn; history; internet; law; shirt; sky/heaven; success	syksy; historia; internet; laki; paita; taivas; menestys	26
164s	culture; economy; ice_cream; leaf/newspaper; planet	kulttuuri; talous; jäätelö; lehti; planeetta	25
168s	meaning; outer_space; song	merkitys; ulkoavaruus; laulu	24
172s	achievement; bird; boy; confirmation_school_(religion); end	saavutus; lintu; poika; rippikoulu; loppu	23
177s	apartment; being_alive; earth; sex; wish	asunto; elossaoleminen; maapallo; seksi; toive	22
185.5s	arc; bigness; dating; fulfillment; funniness; long_time; man; niceness; rock_'n'_roll; surfboard; technology; wonderfulness	kaari; suuruus; seurustelu; täytyminen; huvittavuus; pitkä_aika; mies/ihminen; somuus; rock_'n'_roll; surffilauta; teknologia; suurenmoisuus	21
200s	age; beauty; being; belief; care; dad; difficulty; girlfriend; golf; reason; roof; silence; smallness; snowboard; survivor; tiger; youth	ikä; kauneus; oleminen; uskomus; hoito; isä; vaikeus; tyttöystävä; golf; syy; katto; hiljaisuus; pienenä; lumilauta; selviytyjä; tiikeri; nuoruus	20
218s	being_together; coal; development; doctor_(physician); freedom_of_speech; gene; getting_wiser; head; hecticness; ideology; injustice; life_cycle; machine; organ; period; physicality; ice skate; ugliness; woman	yhdessäolo; hiili; kehitys; lääkäri; sananvapaus; geeni; viisastuminen; pää; hektisyys; ideologia; epäoikeudenmukaisuus; elämänkaari; kone; elin; valhe; fyysisuus; luistin; rumuus; nainen	19
242s	adventure; biologist; confidence; couple; cross_(symbol); cruelty; dead; dirtiness; ecosystem; electricity; eternity; family_(relatives); feeling; friendship; getting_things_done; loneliness; medicine (discipline);	seikkailu; biologi; tyytyväisyys; pari/pariskunta; risti; julmuus; kuollut; likaisuus; ekosysteemi; sähkö; ikuisuus; suku; tuntemus; ystävyys; aikaansaavuus; yksinäisyys; lääketiede; henkinen kehitys; maito;	18

	mental_development; milk; old; past; school_institution; sealife; social_life; spirituality; star; tradition; transition; zebra	vanha; menneisyys; koululaitos; merielämä; sosiaalinen_elämä; hengellisyys; tähti; perinne; siirtymä; seepra	
269s	accessory; balance; being_(person/animal); depressiveness; duty; easy; elder; expedition; fastness; game; getting_along; giraffe; girl; home_country; mammal; neighbor; rna; satisfaction; shelter; single-home_house; sleeping; survival; teaching; videogame_device; volleyball	varuste; tasapaino; olento; masentavuus; velvollisuus; helppo; vanhus; tutkimusmatka; nopeus; peli; viihtyvyys; kirahvi; tyttö; kotimaa; nisäkäs; naapuri; rna; tyydytys; suoja; omakotitalo; nukkuminen; selviytyminen; opetus; videopelilaitte; lentopallo	17
290s	activity; belonging; camp; colonization; conscience; diversity; scariness; flame; futility; getting_dumber; having_fun; interactiveness; lifestyle; moment; problem; target_of_attention; weirdness	toiminta; kuuluvuus; leiri; löytöretkeily; omatunto; monimuotoisuus; pelottavuus; liekki; turhuus; tyhmistyminen; hauskanpito; vuorovaikutteisuus; elämäntapa; hetki; ongelma; mielenkiinnon_kohde; omituisuus	16
309.5s	accident; adolescence; animal_kingdom; beginning; candle; circulation_(rotation); color; drinking; enjoying; foreign_country; hardness; human_relationship; laptop; loss; minute; mobile_phone; rose; smile; spouse; stress; undersea; vocation	onnettomuus; nuoruus; eläinkunta; alku; kynttilä; kiertokulku; väri; juominen; nauttiminen; ulkoma; kovuus; ihmissuhde; kannettava; menetys; minuutti; kännykkä; ruusu; hymy; puoliso; stressi; merenalainen; kutsumus	15
332.5s	atom; breath; bug; exploration; eyeglasses; guitar; information; knowledge; lifetime; loveliness; marine_life; memory; mind; movie; mp3_player; passing_time; privacy; show; spoon; strangeness; string_of_life; tobacco; view_(opinion); yard_(garden)	atomi; hengitys; ötökkä; tutkiminen; silmälasit; kitara; tieto; tietämys; elinaika; ihanuus; merellinen_elämä; muisto; mieli; elokuva; mp3-soitin; ajan_viettäminen; yksityisyys; suihku; lusikka; outous; elämänlanka; tupakka; näkemys; piha	14
355s	adrenaline; attitude; bag; birthday; body-training; defeat; engagement_(prior_wedding); fashion; fishery; gender; ham; lawn; ocean; organs_(entity); photosynthesis; question; reading; residing; study_book; table; variation	adrenaliini; asenne; laukku; syntymäpäivä; kehonrakennus; häviö; kihlat; muoti; kalastusyhdistö; sukupuoli; kinkku; nurmikko; valtameri; elimistö; fotosynteesi; kysymys; lukeminen; asuminen; oppikirja; pöytä; vaihtelevuus	13
376.5s	bear; cell_phone; combat; community; farm_(farmhouse); fruit; funeral; habit; hairspray; helping; item; massacre; match_(for_firing); moving_(changing_location_of_home); outlook; park; passion; producer; property_(belongings); responsibility; sky; tennis	karhu; matkapuhelin; kamppailu; yhteisö; maatila; hedelmä; hautajaiset; tapa; hiuslakka; auttaminen; kappale; joukkotuho; tulitikki; muutto; katsomus; puisto; intohimo; tuottaja; omaisuus; vastuuntunto; taivas; tennis	12
398.5s	adversity; chicken; class; coffee_cup; competition; globalization; heredity; hope; market_(economics); molecule; motorcycle; personality; property; realisticness; separation/divorce; sign; skateboard; string_(of_clothing); suicide; suspense; thinking; worry	vastoinkäyminen; kana; luokka; kahvikuppi; kilpailu; globalisoituminen; perinnöllisyys; toivo; markkinat; molekyyli; moottoripyörä; persoona; omaisuus; todenmukaisuus; ero; merkki; skeittilauta; lanka; itsemurha; jännitys; ajattelu; huoli	11
418s	admiration; bacteria; beach; candy; chair; criminal; decomposer; grandmother; hotness; ink; meat; pelvis; potential; prison; shine; surviving; thought	ihailu; bakteeri; ranta; makeinen; tuoli; rikollinen; hajottaja; isoäiti; kuumuus; muste; liha; lonkka; valmius; vankila; paiste; selviytyminen; ajatus	10
434s	basket_ball; bush; change; consumer; effort; greatness; household_work; material; misery; need; pension; shop; space; value; weekday	koripallo; pensas; muutos; kuluttaja; ponnistelu; suurenmoisuus; kotitalous; aine; kurjuus; tarve; eläke; kauppa; avaruus/tila; arvo; arki	9
449s	beer; behavior; building; cloud; day; duck; handsomeness; heritage; lake; lungs; nightclub; room_(in_apartment); sock; start; uniqueness	olut; käytös; rakennus; pilvi; päivä; ankka; komeus; perintö; järvi; keuhkot; yökerho; huone; sukka; alku; ainutlaatuisuus	8
465s	agreement; assignment; awesomeness; birch; entertainment; event; fire; glacier; homework; hurting; living_room; longing; night; robot; rock_(ground_material); soul; trap	sopimus; tehtävä; hurjuus; koivu; viihde; tapahtuma; tuli; jäätikkö; läksyt; sattuminen_(kipu); olohuone; kaipa; yö; robotti; kallio; sielu; ansa	7
483.5s	angriness; baptism_ceremony; biodiversity; church; fence; film; heaven; living_region; noise; play_age; politics; record_(new_achievement); road; sunshine; teen; understanding; unfairness; volcano; warmth; weather	vihaisuus; kastejuhla; luonnon_monimuotoisuus; kirkko; aita; filmi; taivas; asuinpaikka; melu; leikki-ikä; politiikka; ennätys; tie; auringonpaiste; teini; ymmärtäminen; väärä; tulivuori; lämpö; sää	6
506s	angel; catastrophe; coffin; complicatedness; cottage; darkness; diagnose; electronics; evilness; fur; longness; mad; medicine_(healing_chemical); miracle; nailpolish; performance; phoenix; physics; playing_(sports/game); singing; skill; sofa; spring; sunlight; swimming	enkeli; katastrofi; arkku; mutkikkaus; mökki; pimeys; diagnoosi; elektroniikka; pahuus; turkki; pituus; mielipuolinen; lääke; ihme; kynsilakka; suoritus; feeniks; fysiikka; pelaaminen; laulaminen; taito; sohva; kevät; auringonvalo; uiminen	5
526s	badness; ball; bank_(money); bill_(payment); countryside; fail; ghost; joke; kindergarten; leaf_of_lettuce; misfortune; pool_(small_lake); relaxing; trip; wall_(of_room)	huonous; pallo; pankki; lasku; maaseutu; epäonnistuminen; haamu; vitsi; tarha; salaatinlehti; epäonni; lampi; rentoutuminen; retki; seinä	4
541s	body; cheese; cider; coffee; course; driving_licence; scare; lighter_(for_firing); mandatoriness; naturalness; notebook; regeneration; shortness; snow; tax	ruumis; juusto; siideri; kahvi; kurssi; ajokortti; pelko; syytin; pakollisuus; luonnollisuus; vihko; uusiuuminen_(regeneraatio); lyhyys; lumi; vero	3
555s	bar_(restaurant); bow_tie; carrot; challenge; death_penalty; forty-two; grass_(lawn); honey; lamp; limitedness; magic; mouse; wolf	baari; rusetti; porkkana; haaste; kuolemanrangaistus; neljäkymmentäkaksi; ruoho; hunaja; lamppu; rajallisuus; taika; hiiri; susi	2
591.5s	bond_(economics); calmness; cave; christmas; climax; climbing; closet; costume; convenience; degree_(diploma); disc; easiness; energy; eraser; flute; flying; fog; football; godship; government; guess; hair; hatred; hedgehog; honesty; kindness; knowing; life-givingness; loudspeaker; middle-ageness; minister_(politics); moon; mountain; normality; patriotism; pencil_case; plane; predator; pregnancy; president; prey;	joukkovielkakirja; rauhallisuus; luola; joulu; huippukohta; kiipeäminen; kaappi; asu; mukavuus; tutkinto; kiekko; helppous; energia; kumi; huilu; lentäminen; sumu; jalkapallo; palvonta; eduskunta; veikkaus; hiukset; vihaisuus; siili; rehellisyys; ystävällisyys; tietäminen; elämän_mahdollistaminen; kaiutin; keski-ikäisyys; ministeri; kuu; vuori; tavallisuus; isänmaanrakkaus; penaali; lentokone; peto; raskaus;	1

	rectangle; respect; senate; sharpener_(for_pencils); shelf; slowness; square; stock_(economics); style; talent; teaching_children; thing; uneven; vitamin; walking; well-being; window; winter; writing	presidentti; saalis; ruutu; kunnioittaminen; hallitus; teroitin; hylly; hitaus; neliö; osake; tyyli; kyky; lastenkasvatus; asia/esine; epätasaisuus; vitamiini; käveleminen; hyvinvointi; ikkuna; talvi; kirjoittaminen	
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Appendix R

This table shows heuristically approximated activity frequencies for four collaborator roles of Competing Values Framework in respect to 12 activities that we published in Table 2 of publication [P1] titled “Some approximated relative activity frequencies for each collaborator role”. Please note that in later additional experiments we empirically gained activity frequencies for these activities as show in Table 4.3 in Chapter 4 of current publication and we suggest giving specific attention to those empirically gained values.

<i>Activity</i>	<i>Create role</i>	<i>Compete role</i>	<i>Control role</i>	<i>Collaborate role</i>
Submits ideas	0.40	0.10	0.20	0.30
Adds nodes to concept map	0.40	0.30	0.10	0.20
Adds arcs to concept map	0.20	0.10	0.30	0.40
Makes references to ideas	0.30	0.10	0.40	0.20
Makes references to concept map	0.10	0.30	0.20	0.40
Comments ideas	0.10	0.20	0.40	0.30
Comments concept map	0.30	0.40	0.10	0.20
Sends coordination messages	0.10	0.40	0.20	0.30
Synthesizes ideas to concept map	0.20	0.10	0.40	0.30
Distributes topics from concept map to reconsideration	0.10	0.20	0.30	0.40
Explores accordance of ideas and concept map	0.40	0.30	0.20	0.10
Requests stimulation for creative thinking	0.10	0.40	0.30	0.20

Appendix S

We generated the shortest paths between 10 highest-ranking start concepts (including (occurrences in parenthesis): human (121), food (93), water (85), nature (79), entertainment (74), transport (72), nutrition (68), mind (66), infrastructure (65), globalization (63)) and 12 highest-ranking end concepts (including (occurrences in parenthesis): animal (108), human (106), water (106), earth (101), mammal (98), psychology (92), philosophy (90), law (86), religion (85), protein (85), science (80), carbon dioxide (80)) in Wikipedia hyperlinks connecting nouns of vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile as shown in Table 12.9.

This first listing below shows all 628 shortest routes between 118 pairs of concepts that contained together 1393 hyperlinks of which 736 were unique. Among routes between 118 pairs of concepts 3 pairs of concepts had shortest paths containing three hyperlinks (on average 58.3 parallel paths between each pair of concepts), 78 pairs of concepts had shortest path containing two hyperlinks (on average 5.3 parallel paths between each pair of concepts) and 37 pairs of concepts had shortest paths containing one hyperlink (on average 1.0 parallel paths between each pair of concepts). The shortest paths are listed in alphabetical order so that possible parallel routes of the shortest paths between each pair of concepts are mentioned consecutively.

628 shortest routes between 118 pairs of concepts
<p><i>Shortest paths containing three hyperlinks:</i> entertainment->animation->light->earth; entertainment->ball->sphere->earth; entertainment->camping->cold->earth; entertainment->camping->electricity->earth; entertainment->camping->water->earth; entertainment->ceremony->battle->earth; entertainment->cooking->carbon->earth; entertainment->dance->rainforest->earth; entertainment->education->biology->earth; entertainment->employment->globalization->earth; entertainment->festival->season->earth; entertainment->film->sound->earth; entertainment->film->technology->earth; entertainment->leisure->time->earth; entertainment->literature->nature->earth; entertainment->monkey->human->earth; entertainment->music->biology->earth; entertainment->music->globalization->earth; entertainment->music->physics->earth; entertainment->music->sound->earth; entertainment->music->time->earth; entertainment->novel->globalization->earth; entertainment->poetry->globalization->earth; entertainment->radio->atom->earth; entertainment->radio->horizon->earth; entertainment->radio->light->earth; entertainment->radio->technology->earth; entertainment->rhythm->time->earth; entertainment->running->oxygen->earth; entertainment->running->speed->earth; entertainment->singing->human->earth; entertainment->stadium->steel->earth; entertainment->television->angle->earth; entertainment->writer->astronomy->earth; entertainment->writer->biology->earth; entertainment->writer->physics->earth; entertainment->zoo->extinction->earth; infrastructure->bridge->river->mammal; infrastructure->bus->camel->mammal; infrastructure->climate change->fish->mammal; infrastructure->coal->iron->mammal; infrastructure->communication->human->mammal; infrastructure->communication->sound->mammal; infrastructure->earthquake->earth->mammal; infrastructure->economy->iron->mammal; infrastructure->electricity->earth->mammal; infrastructure->electricity->music->mammal; infrastructure->electricity->shark->mammal; infrastructure->government->fear->mammal; infrastructure->museum->animal->mammal; infrastructure->museum->zoo->mammal; infrastructure->noise->sound->mammal; infrastructure->organization->human->mammal; infrastructure->road->river->mammal; infrastructure->storm->desert->mammal; infrastructure->storm->earth->mammal; infrastructure->storm->rainforest->mammal; infrastructure->sustainability->climate->mammal; infrastructure->sustainability->earth->mammal; infrastructure->sustainability->meat->mammal; infrastructure->sustainability->river->mammal; infrastructure->telephone->sound->mammal; infrastructure->trail->horse->mammal; infrastructure->transport->cattle->mammal; infrastructure->transport->horse->mammal; infrastructure->transport->human->mammal; infrastructure->transport->river->mammal; infrastructure->water->acid->mammal; infrastructure->water->climate->mammal; infrastructure->water->desert->mammal; infrastructure->water->earth->mammal; infrastructure->water->fish->mammal; infrastructure->water->human->mammal; infrastructure->water->life->mammal; infrastructure->water->river->mammal; infrastructure->water->whale->mammal; infrastructure->weapon->horse->mammal; infrastructure->weapon->hunting->mammal; infrastructure->vehicle->camel->mammal; infrastructure->wheel->cattle->mammal; infrastructure->wheel->horse->mammal; infrastructure->wheel->iron->mammal; mind->adaptation->climate->carbon dioxide; mind->art->globalization->carbon dioxide; mind->art->pollution->carbon dioxide; mind->awareness->animal->carbon dioxide; mind->biology->agriculture->carbon dioxide; mind->biology->animal->carbon dioxide; mind->biology->bacteria->carbon dioxide; mind->biology->climate->carbon dioxide; mind->biology->earth->carbon dioxide; mind->biology->ecology->carbon dioxide; mind->biology->energy->carbon dioxide; mind->biology->plant->carbon dioxide; mind->body->insect->carbon dioxide; mind->body->meat->carbon dioxide; mind->brain->alcohol->carbon dioxide; mind->brain->insect->carbon dioxide; mind->communication->bacteria->carbon dioxide; mind->communication->plant->carbon dioxide; mind->computer->washing machine->carbon dioxide; mind->conscience->animal->carbon dioxide; mind->conscience->carbon footprint->carbon dioxide; mind->conscience->earth->carbon dioxide; mind->conscience->ecology->carbon dioxide; mind->economics->globalization->carbon dioxide; mind->economics->pollution->carbon dioxide; mind->engineering->chemistry->carbon dioxide; mind->engineering->energy->carbon dioxide; mind->evolution->ant->carbon dioxide; mind->evolution->atmosphere->carbon dioxide; mind->evolution->bacteria->carbon dioxide; mind->evolution->crocodile->carbon dioxide; mind->evolution->earth->carbon dioxide; mind->evolution->ecology->carbon dioxide; mind->evolution->global warming->carbon dioxide; mind->evolution->insect->carbon dioxide; mind->evolution->oxygen->carbon dioxide; mind->evolution->plant->carbon dioxide; mind->evolution->virus->carbon dioxide; mind->family->animal->carbon dioxide; mind->fear->water->carbon dioxide; mind->gene->bacteria->carbon dioxide; mind->gene->virus->carbon dioxide; mind->human->agriculture->carbon dioxide; mind->human->earth->carbon dioxide; mind->human->global warming->carbon dioxide; mind->human->globalization->carbon dioxide; mind->human->pollution->carbon dioxide; mind->human->transport->carbon dioxide; mind->idea->fish->carbon</p>

dioxide; mind->language->globalization->carbon dioxide; mind->learning->energy->carbon dioxide; mind->life->animal->carbon dioxide; mind->life->bacteria->carbon dioxide; mind->life->carbon->carbon dioxide; mind->life->coal->carbon dioxide; mind->life->earth->carbon dioxide; mind->life->ecology->carbon dioxide; mind->life->fish->carbon dioxide; mind->life->insect->carbon dioxide; mind->life->oxygen->carbon dioxide; mind->life->plant->carbon dioxide; mind->life->virus->carbon dioxide; mind->machine->energy->carbon dioxide; mind->machine->engine->carbon dioxide; mind->machine->fuel->carbon dioxide; mind->materialism->energy->carbon dioxide; mind->matter->atom->carbon dioxide; mind->matter->chemistry->carbon dioxide; mind->matter->earth->carbon dioxide; mind->matter->energy->carbon dioxide; mind->matter->gas->carbon dioxide; mind->matter->liquid->carbon dioxide; mind->matter->water->carbon dioxide; mind->perception->ecology->carbon dioxide; mind->pie->bread->carbon dioxide; mind->pie->flour->carbon dioxide; mind->pie->sea->carbon dioxide; mind->psychology->chemistry->carbon dioxide; mind->reality->energy->carbon dioxide; mind->science->chemistry->carbon dioxide; mind->science->energy->carbon dioxide; mind->skull->animal->carbon dioxide; mind->spirit->blood->carbon dioxide; mind->taste->acid->carbon dioxide; mind->taste->alcohol->carbon dioxide; mind->taste->beer->carbon dioxide; mind->taste->blood->carbon dioxide; mind->taste->meat->carbon dioxide; mind->taste->soft drink->carbon dioxide; mind->taste->wine->carbon dioxide; mind->tool->agriculture->carbon dioxide; mind->tool->animal->carbon dioxide; mind->tool->truck->carbon dioxide

Shortest paths containing two hyperlinks:

entertainment->dance->animal; entertainment->public transport->carbon dioxide; entertainment->monkey->human; entertainment->singing->human; entertainment->gambling->law; entertainment->literature->law; entertainment->zoo->mammal; entertainment->education->philosophy; entertainment->literature->philosophy; entertainment->writer->philosophy; entertainment->cooking->protein; entertainment->artificial intelligence->psychology; entertainment->clown->psychology; entertainment->education->psychology; entertainment->game->psychology; entertainment->imagination->psychology; entertainment->insight->psychology; entertainment->music->psychology; entertainment->novel->psychology; entertainment->festival->religion; entertainment->literature->religion; entertainment->writer->religion; entertainment->education->science; entertainment->joke->science; entertainment->camping->water; food->acid->carbon dioxide; food->agriculture->carbon dioxide; food->animal->carbon dioxide; food->bacteria->carbon dioxide; food->blood->carbon dioxide; food->bread->carbon dioxide; food->ecology->carbon dioxide; food->energy->carbon dioxide; food->fish->carbon dioxide; food->fuel->carbon dioxide; food->kidney->carbon dioxide; food->meat->carbon dioxide; food->plant->carbon dioxide; food->potato->carbon dioxide; food->rice->carbon dioxide; food->virus->carbon dioxide; food->bacteria->earth; food->evolution->earth; food->fuel->earth; food->human->earth; food->sustainability->earth; food->famine->law; food->human->law; food->sustainability->law; food->acid->mammal; food->animal->mammal; food->butter->mammal; food->evolution->mammal; food->fish->mammal; food->human->mammal; food->immune system->mammal; food->kidney->mammal; food->meat->mammal; food->milk->mammal; food->muscle->mammal; food->seed->mammal; food->human->philosophy; food->human->psychology; food->evolution->religion; food->human->religion; food->ecology->science; food->human->science; food->sustainability->science; food->blood->water; food->bread->water; food->energy->water; food->fruit->water; food->honey->water; food->kidney->water; food->milk->water; food->plant->water; food->salt->water; food->soup->water; food->steam->water; food->sugar->water; food->sustainability->water; food->vinegar->water; food->vitamin->water; globalization->habitat->animal; globalization->life->animal; globalization->nature->animal; globalization->tiger->animal; globalization->communication->human; globalization->community->human; globalization->culture->human; globalization->earth->human; globalization->health->human; globalization->nature->human; globalization->transport->human; globalization->wealth->human; globalization->crime->law; globalization->democracy->law; globalization->economist->law; globalization->famine->law; globalization->liberty->law; globalization->philosophy->law; globalization->religion->law; globalization->sustainability->law; globalization->tax->law; globalization->earth->mammal; globalization->life->mammal; globalization->nature->mammal; globalization->river->mammal; globalization->tiger->mammal; globalization->carbon dioxide->protein; globalization->life->protein; globalization->crime->psychology; globalization->culture->psychology; globalization->health->psychology; globalization->philosophy->psychology; globalization->economics->science; globalization->knowledge->science; globalization->life->science; globalization->nature->science; globalization->religion->science; globalization->sustainability->science; globalization->technology->science; globalization->carbon dioxide->water; globalization->global warming->water; globalization->health->water; globalization->river->water; globalization->sustainability->water; globalization->tiger->water; globalization->transport->water; human->digestion->animal; human->family->animal; human->female->animal; human->genetics->animal; human->reproduction->animal; human->species->animal; human->tool->animal; human->agriculture->carbon dioxide; human->earth->carbon dioxide; human->global warming->carbon dioxide; human->globalization->carbon dioxide; human->pollution->carbon dioxide; human->transport->carbon dioxide; human->cooking->protein; human->digestion->protein; human->evolution->protein; human->gene->protein; human->genetics->protein; human->hunting->protein; human->mammal->protein; human->competition->water; human->fire->water; human->global warming->water; human->health->water; human->motivation->water; human->space->water; human->transport->water; infrastructure->museum->animal; infrastructure->coal->carbon dioxide; infrastructure->energy->carbon dioxide; infrastructure->public transport->carbon dioxide; infrastructure->storm->carbon dioxide; infrastructure->transport->carbon dioxide; infrastructure->water->carbon dioxide; infrastructure->earthquake->earth; infrastructure->electricity->earth; infrastructure->storm->earth; infrastructure->sustainability->earth; infrastructure->water->earth; infrastructure->communication->human; infrastructure->organization->human; infrastructure->transport->human; infrastructure->water->human; infrastructure->college->law; infrastructure->institution->law; infrastructure->ownership->law; infrastructure->police->law; infrastructure->road->law; infrastructure->sustainability->law; infrastructure->government->philosophy; infrastructure->museum->philosophy; infrastructure->energy->protein; infrastructure->water->protein; infrastructure->organization->psychology; infrastructure->city->religion; infrastructure->institution->religion; infrastructure->society->religion; infrastructure->university->religion; infrastructure->government->science; infrastructure->museum->science; infrastructure->primary school->science; infrastructure->secondary school->science; infrastructure->sustainability->science; infrastructure->university->science; mind->awareness->animal; mind->biology->animal; mind->conscience->animal; mind->family->animal; mind->life->animal; mind->skull->animal; mind->tool->animal; mind->biology->earth; mind->conscience->earth; mind->evolution->earth; mind->human->earth; mind->life->earth; mind->matter->earth; mind->emotion->law; mind->human->law; mind->philosophy->law; mind->reason->law; mind->religion->law; mind->spirit->law; mind->emotion->mammal; mind->evolution->mammal; mind->fear->mammal; mind->human->mammal; mind->intelligence->mammal; mind->learning->mammal; mind->life->mammal; mind->love->mammal; mind->skull->mammal; mind->biology->protein; mind->evolution->protein; mind->gene->protein; mind->life->protein; mind->fear->water; mind->matter->water; nature->animal->carbon dioxide; nature->atmosphere->carbon dioxide; nature->bacteria->carbon dioxide; nature->earth->carbon dioxide; nature->energy->carbon dioxide; nature->fish->carbon dioxide; nature->gas->carbon dioxide; nature->ice->carbon dioxide; nature->liquid->carbon dioxide; nature->oxygen->carbon dioxide; nature->planet->carbon dioxide; nature->plant->carbon dioxide; nature->pollution->carbon dioxide; nature->sea->carbon dioxide; nature->sun->carbon dioxide; nature->volcano->carbon dioxide; nature->civilization->law; nature->human->law; nature->wilderness->law; nature->art->philosophy; nature->consciousness->philosophy; nature->extinction->philosophy; nature->human->philosophy; nature->life->philosophy; nature->materialism->philosophy; nature->mind->philosophy; nature-

<p>>phenomenon->philosophy; nature->physics->philosophy; nature->science->philosophy; nature->animal->protein; nature->bacteria->protein; nature->biology->protein; nature->bone->protein; nature->digestion->protein; nature->dinosaur->protein; nature->dna->protein; nature->energy->protein; nature->evolution->protein; nature->fishing->protein; nature->genetics->protein; nature->hunting->protein; nature->life->protein; nature->mammal->protein; nature->muscle->protein; nature->oxygen->protein; nature->temperature->protein; nature->biology->psychology; nature->consciousness->psychology; nature->human->psychology; nature->laboratory->psychology; nature->mind->psychology; nature->science->psychology; nature->civilization->religion; nature->evolution->religion; nature->human->religion; nature->life->religion; nature->mind->religion; nature->planet->religion; nature->science->religion; nature->cloud->water; nature->energy->water; nature->extinction->water; nature->fishing->water; nature->ice->water; nature->liquid->water; nature->matter->water; nature->ocean->water; nature->oxygen->water; nature->physics->water; nature->planet->water; nature->plant->water; nature->river->water; nature->steam->water; nutrition->blood->animal; nutrition->digestion->animal; nutrition->dna->animal; nutrition->food->animal; nutrition->fruit->animal; nutrition->genetics->animal; nutrition->immune system->animal; nutrition->leaf->animal; nutrition->life->animal; nutrition->seed->animal; nutrition->agriculture->carbon dioxide; nutrition->atmosphere->carbon dioxide; nutrition->blood->carbon dioxide; nutrition->bread->carbon dioxide; nutrition->carbon->carbon dioxide; nutrition->energy->carbon dioxide; nutrition->iron->carbon dioxide; nutrition->leaf->carbon dioxide; nutrition->meat->carbon dioxide; nutrition->oxygen->carbon dioxide; nutrition->potato->carbon dioxide; nutrition->rice->carbon dioxide; nutrition->water->carbon dioxide; nutrition->wine->carbon dioxide; nutrition->atmosphere->earth; nutrition->carbon->earth; nutrition->dna->earth; nutrition->human->earth; nutrition->iron->earth; nutrition->life->earth; nutrition->oxygen->earth; nutrition->soil->earth; nutrition->sunlight->earth; nutrition->technology->earth; nutrition->water->earth; nutrition->human->law; nutrition->butter->mammal; nutrition->digestion->mammal; nutrition->human->mammal; nutrition->immune system->mammal; nutrition->iron->mammal; nutrition->life->mammal; nutrition->meat->mammal; nutrition->milk->mammal; nutrition->seed->mammal; nutrition->experiment->philosophy; nutrition->human->philosophy; nutrition->life->philosophy; nutrition->psychology->philosophy; nutrition->science->philosophy; nutrition->herb->religion; nutrition->human->religion; nutrition->life->religion; nutrition->science->religion; transport->cattle->animal; transport->horse->animal; transport->landing->animal; transport->ocean->animal; transport->team->animal; transport->globalization->earth; transport->human->earth; transport->ocean->earth; transport->soil->earth; transport->steel->earth; transport->technology->earth; transport->water->earth; transport->human->law; transport->road->law; transport->tax->law; transport->cattle->mammal; transport->horse->mammal; transport->human->mammal; transport->river->mammal; transport->education->philosophy; transport->globalization->philosophy; transport->government->philosophy; transport->human->philosophy; transport->beer->protein; transport->carbon dioxide->protein; transport->water->protein; transport->wool->protein; transport->education->psychology; transport->human->psychology; transport->city->religion; transport->globalization->religion; transport->human->religion; transport->education->science; transport->government->science; transport->human->science; transport->technology->science; water->biology->animal; water->dna->animal; water->fish->animal; water->life->animal; water->whale->animal; water->human->law; water->politics->law; water->acid->mammal; water->climate->mammal; water->desert->mammal; water->earth->mammal; water->fish->mammal; water->human->mammal; water->life->mammal; water->river->mammal; water->whale->mammal; water->human->philosophy; water->life->philosophy; water->biology->psychology; water->human->psychology; water->human->religion; water->life->religion; water->human->science; water->life->science; water->politics->science</p> <p><i>Shortest paths containing one hyperlink:</i> food->animal; food->human; food->protein; globalization->carbon dioxide; globalization->carbon dioxide; globalization->earth; globalization->philosophy; globalization->religion; human->bikini; human->earth; human->law; human->mammal; human->philosophy; human->religion; human->science; infrastructure->water; mind->bikini; mind->human; mind->philosophy; mind->religion; mind->science; nature->animal; nature->earth; nature->human; nature->mammal; nature->science; nutrition->bikini; nutrition->human; nutrition->protein; nutrition->science; nutrition->water; transport->carbon dioxide; transport->human; transport->water; water->carbon dioxide; water->earth; water->human; water->protein</p>
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This second listing below shows among 1393 hyperlinks those hyperlinks that occurred most often in shortest paths between 118 pairs of concepts. This listing contains all occurrence levels of hyperlinks whereas Table 12.10 was limited to shown only those hypelinks that had at least 5 occurrences.

Most occurring hyperlinks among 1393 hyperlinks between 118 pairs of concepts
<i>Hyperlinks having 15 occurrences:</i> mind->life
<i>Hyperlinks having 14 occurrences:</i> infrastructure->water; mind->evolution
<i>Hyperlinks having 13 occurrences:</i> (no hyperlinks having 13 occurrences)
<i>Hyperlinks having 12 occurrences:</i> energy->carbon dioxide
<i>Hyperlinks having 11 occurrences:</i> human->mammal; mind->biology; transport->human
<i>Hyperlinks having 10 occurrences:</i> mind->human
<i>Hyperlinks having 9 occurrences:</i> animal->carbon dioxide; globalization->carbon dioxide; human->earth; mind->matter; water->human
<i>Hyperlinks having 8 occurrences:</i> earth->carbon dioxide; food->human; globalization->earth; river->mammal
<i>Hyperlinks having 7 occurrences:</i> bacteria->carbon dioxide; earth->mammal; human->law; infrastructure->sustainability; mind->taste; water->earth
<i>Hyperlinks having 6 occurrences:</i> agriculture->carbon dioxide; ecology->carbon dioxide; entertainment->music; human->philosophy; human->religion; infrastructure->transport; mind->conscience; nature->human; nutrition->human; plant->carbon dioxide; water->life;
<i>Hyperlinks having 5 occurrences:</i> biology->earth; entertainment->writer; horse->mammal; infrastructure->museum; infrastructure->storm; life->animal; life->mammal; nature->science; nutrition->life; pollution->carbon dioxide; transport->carbon dioxide;

transport->water; water->carbon dioxide;
<p><i>Hyperlinks having 4 occurrences:</i></p> <p>blood->carbon dioxide; chemistry->carbon dioxide; entertainment->camping; entertainment->education; entertainment->literature; entertainment->radio; fish->carbon dioxide; fish->mammal; food->animal; food->sustainability; globalization->life; globalization->nature; globalization->philosophy; globalization->religion; human->psychology; human->science; infrastructure->electricity; insect->carbon dioxide; iron->mammal; meat->carbon dioxide; mind->tool; nature->animal; oxygen->carbon dioxide; technology->earth; virus->carbon dioxide;</p>
<p><i>Hyperlinks having 3 occurrences:</i></p> <p>acid->mammal; atmosphere->carbon dioxide; biology->animal; bread->carbon dioxide; cattle->mammal; climate->mammal; communication->human; desert->mammal; electricity->earth; evolution->earth; evolution->protein; family->animal; food->evolution; food->kidney; global warming->carbon dioxide; globalization->health; globalization->sustainability; globalization->tiger; human->global warming; human->transport; infrastructure->communication; infrastructure->government; infrastructure->organization; infrastructure->wheel; life->earth; life->philosophy; life->protein; life->religion; matter->water; meat->mammal; mind->fear; mind->gene; mind->machine; mind->philosophy; mind->pie; mind->religion; mind->science; mind->skull; nature->earth; nature->energy; nature->life; nature->mammal; nature->mind; nature->oxygen; nature->planet; nutrition->iron; nutrition->science; nutrition->water; sound->mammal; sustainability->earth; sustainability->law; sustainability->science; time->earth; tool->animal; transport->cattle; transport->education; transport->globalization; transport->horse; water->fish; water->protein; water->whale;</p>
<p><i>Hyperlinks having 2 occurrences:</i></p> <p>acid->carbon dioxide; alcohol->carbon dioxide; animal->mammal; awareness->animal; biology->protein; biology->psychology; butter->mammal; camel->mammal; camping->water; carbon->carbon dioxide; carbon->earth; carbon dioxide->protein; city->religion; climate->carbon dioxide; coal->carbon dioxide; conscience->animal; conscience->earth; cooking->protein; digestion->animal; digestion->protein; dna->animal; earthquake->earth; education->philosophy; education->psychology; education->science; energy->protein; energy->water; entertainment->cooking; entertainment->dance; entertainment->festival; entertainment->film; entertainment->monkey; entertainment->novel; entertainment->running; entertainment->singing; entertainment->zoo; evolution->mammal; evolution->religion; famine->law; fear->mammal; fear->water; food->acid; food->bacteria; food->blood; food->bread; food->ecology; food->energy; food->fish; food->fuel; food->meat; food->milk; food->plant; fuel->carbon dioxide; gas->carbon dioxide; gene->protein; genetics->animal; genetics->protein; global warming->water; globalization->crime; globalization->culture; globalization->river; globalization->transport; government->philosophy; government->science; health->water; human->agriculture; human->digestion; human->genetics; human->globalization; human->pollution; hunting->protein; immune system->mammal; infrastructure->coal; infrastructure->earthquake; infrastructure->energy; infrastructure->institution; infrastructure->road; infrastructure->university; infrastructure->weapon; life->science; light->earth; liquid->carbon dioxide; mammal->protein; matter->earth; milk->mammal; mind->art; mind->awareness; mind->body; mind->brain; mind->communication; mind->economics; mind->emotion; mind->engineering; mind->family; mind->learning; mind->psychology; mind->spirit; monkey->human; muscle->mammal; museum->animal; nature->bacteria; nature->biology; nature->civilization; nature->consciousness; nature->evolution; nature->extinction; nature->fishing; nature->ice; nature->liquid; nature->physics; nature->plant; nature->atmosphere; nutrition->blood; nutrition->carbon; nutrition->digestion; nutrition->dna; nutrition->immune system; nutrition->leaf; nutrition->meat; nutrition->oxygen; nutrition->seed; organization->human; oxygen->earth; philosophy->law; physics->earth; plant->water; potato->carbon dioxide; public transport->carbon dioxide; religion->law; rice->carbon dioxide; river->water; road->law; science->philosophy; science->religion; sea->carbon dioxide; seed->mammal; singing->human; skull->animal; soil->earth; sound->earth; steam->water; steel->earth; storm->earth; sustainability->water; tax->law; technology->science; transport->government; transport->ocean; transport->river; transport->technology; water->acid; water->biology; water->climate; water->desert; water->politics; water->river; whale->mammal; wine->carbon dioxide; zoo->mammal;</p>
<p><i>Hyperlinks having 1 occurrences:</i></p> <p>adaptation->climate; angle->earth; animal->protein; animation->light; ant->carbon dioxide; art->globalization; art->philosophy; art->pollution; artificial intelligence->psychology; astronomy->earth; atmosphere->earth; atom->carbon dioxide; atom->earth; bacteria->earth; bacteria->protein; ball->sphere; battle->earth; beer->carbon dioxide; beer->protein; biology->agriculture; biology->bacteria; biology->climate; biology->ecology; biology->energy; biology->plant; blood->animal; blood->water; body->insect; body->meat; bone->protein; brain->alcohol; brain->insect; bread->water; bridge->river; bus->camel; camping->cold; camping->electricity; carbon dioxide->water; carbon footprint->carbon dioxide; cattle->animal; ceremony->battle; civilization->law; civilization->religion; climate change->fish; cloud->water; clown->psychology; coal->iron; cold->earth; college->law; communication->bacteria; communication->plant; communication->sound; community->human; competition->water; computer->washing machine; conscience->carbon footprint; conscience->ecology; consciousness->philosophy; consciousness->psychology; cooking->carbon; crime->law; crime->psychology; crocodile->carbon dioxide; culture->human; culture->psychology; dance->animal; dance->rainforest; democracy->law; digestion->mammal; dinosaur->protein; dna->earth; dna->protein; earth->human; ecology->science; economics->globalization; economics->pollution; economics->science; economist->law; economy->iron; education->biology; electricity->muscle; electricity->shark; emotion->law; emotion->mammal; employment->globalization; engine->carbon dioxide; engineering->chemistry; engineering->energy; entertainment->animation; entertainment->artificial intelligence; entertainment->ball; entertainment->ceremony; entertainment->clown; entertainment->employment; entertainment->gambling; entertainment->game; entertainment->imagination; entertainment->insight; entertainment->joke; entertainment->leisure; entertainment->poetry; entertainment->public transport; entertainment->rhythm; entertainment->stadium; entertainment->television; evolution->ant; evolution->atmosphere; evolution->bacteria; evolution->crocodile; evolution->ecology; evolution->global warming; evolution->insect; evolution->oxygen; evolution->plant; evolution->virus; experiment->philosophy; extinction->earth; extinction->philosophy; extinction->water; female->animal; festival->religion; festival->season; film->sound; film->technology; fire->water; fish->animal; fishing->protein; fishing->water; flour->carbon dioxide; food->agriculture; food->butter; food->famine; food->fruit; food->honey; food->immune system; food->muscle; food->potato; food->protein; food->rice; food->salt; food->seed; food->soup; food->steam; food->sugar; food->vinegar; food->virus; food->vitamin; fruit->animal; fruit->water; fuel->earth; gambling->law; game->psychology; gene->bacteria; gene->virus; globalization->communication; globalization->community; globalization->democracy; globalization->economics; globalization->economist; globalization->famine; globalization->global warming; globalization->habitat; globalization->knowledge; globalization->liberty; globalization->tax; globalization->technology; globalization->wealth; government->fear; habitat->animal; health-</p>

>human; health->psychology; herb->religion; honey->water; horizon->earth; horse->animal; human->bikini; human->competition; human->cooking; human->evolution; human->family; human->female; human->fire; human->gene; human->health; human->hunting; human->motivation; human->reproduction; human->space; human->species; human->tool; hunting->mammal; ice->carbon dioxide; ice->water; idea->fish; imagination->psychology; immune system->animal; infrastructure->bridge; infrastructure->bus; infrastructure->city; infrastructure->climate change; infrastructure->college; infrastructure->economy; infrastructure->noise; infrastructure->ownership; infrastructure->police; infrastructure->primary school; infrastructure->public transport; infrastructure->secondary school; infrastructure->society; infrastructure->telephone; infrastructure->trail; infrastructure->vehicle; insight->psychology; institution->law; institution->religion; intelligence->mammal; iron->carbon dioxide; iron->earth; joke->science; kidney->carbon dioxide; kidney->mammal; kidney->water; knowledge->science; laboratory->psychology; landing->animal; language->globalization; leaf->animal; leaf->carbon dioxide; learning->energy; learning->mammal; leisure->time; liberty->law; life->bacteria; life->carbon; life->coal; life->ecology; life->fish; life->insect; life->oxygen; life->plant; life->virus; liquid->water; literature->law; literature->nature; literature->philosophy; literature->religion; love->mammal; machine->energy; machine->engine; machine->fuel; materialism->energy; materialism->philosophy; matter->atom; matter->chemistry; matter->energy; matter->gas; matter->liquid; milk->water; mind->adaptation; mind->bikini; mind->computer; mind->idea; mind->intelligence; mind->language; mind->love; mind->materialism; mind->perception; mind->reality; mind->reason; motivation->water; muscle->protein; museum->philosophy; museum->science; museum->zoo; music->biology; music->globalization; music->physics; music->psychology; music->sound; music->time; nature->art; nature->atmosphere; nature->bone; nature->cloud; nature->digestion; nature->dinosaur; nature->dna; nature->fish; nature->gas; nature->genetics; nature->hunting; nature->laboratory; nature->materialism; nature->matter; nature->muscle; nature->ocean; nature->phenomenon; nature->pollution; nature->river; nature->sea; nature->steam; nature->sun; nature->temperature; nature->wilderness; nature->volcano; noise->sound; novel->globalization; novel->psychology; nutrition->agriculture; nutrition->bikini; nutrition->bread; nutrition->butter; nutrition->energy; nutrition->experiment; nutrition->food; nutrition->fruit; nutrition->genetics; nutrition->herb; nutrition->milk; nutrition->potato; nutrition->protein; nutrition->psychology; nutrition->rice; nutrition->soil; nutrition->sunlight; nutrition->technology; nutrition->wine; ocean->animal; ocean->earth; ocean->water; organization->psychology; ownership->law; oxygen->protein; oxygen->water; perception->ecology; phenomenon->philosophy; philosophy->psychology; physics->philosophy; physics->water; pie->bread; pie->flour; pie->sea; planet->carbon dioxide; planet->religion; planet->water; poetry->globalization; police->law; politics->law; politics->science; primary school->science; psychology->chemistry; psychology->philosophy; radio->atom; radio->horizon; radio->light; radio->technology; rainforest->earth; rainforest->mammal; reality->energy; reason->law; religion->science; reproduction->animal; rhythm->time; road->river; running->oxygen; running->speed; salt->water; science->chemistry; science->energy; science->psychology; season->earth; secondary school->science; seed->animal; shark->mammal; skull->mammal; society->religion; soft drink->carbon dioxide; soup->water; space->water; species->animal; speed->earth; sphere->earth; spirit->blood; spirit->law; stadium->steel; storm->carbon dioxide; storm->desert; storm->rainforest; sugar->water; sun->carbon dioxide; sunlight->earth; sustainability->climate; sustainability->meat; sustainability->river; taste->acid; taste->alcohol; taste->beer; taste->blood; taste->meat; taste->soft drink; taste->wine; team->animal; telephone->sound; television->angle; temperature->protein; tiger->animal; tiger->mammal; tiger->water; tool->agriculture; tool->truck; trail->horse; transport->beer; transport->city; transport->landing; transport->road; transport->soil; transport->steel; transport->tax; transport->team; transport->wool; truck->carbon dioxide; university->religion; university->science; washing machine->carbon dioxide; water->dna; wealth->human; weapon->horse; weapon->hunting; vehicle->camel; whale->animal; wheel->cattle; wheel->horse; wheel->iron; wilderness->law; vinegar->water; vitamin->water; volcano->carbon dioxide; wool->protein; writer->astronomy; writer->biology; writer->philosophy; writer->physics; writer->religion; zoo->extinction;

Appendix T

After publication of the publication [P1] we carried out empirical experiments of collaborative concept map construction process in small groups containing persons having ages in range of 15-18 years and representing four collaborator roles of Competing Values Framework ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23-24)). Before introducing collaborative concept map construction process to the student, we identified for each student which of four major collaborator roles (shown in Table 4.3 (originally published as Table 2 in publication [P1])) he represents by a questionnaire that is shown here in this Appendix T. Without revealing in advance what is the purpose of the questionnaire we asked the student to fill in this competing values self-assessment questionnaire that is adapted from Quinn et al. ((Quinn et al. 1990, especially table 1.2 on page 21); (Quinn et al. 1996, especially table 1.2 on pages 23-24)) and among the six sets of four questions corresponding to each four major collaborator roles the one which received highest number of points was selected as the role of the student for collaborative concept map construction process in small groups. In the questionnaire questions 1-6 concern having characteristics of innovator-broker role, then questions 7-12 producer-director role, next questions 13-18 coordinator-monitor role and finally then questions 19-24 facilitator-mentor role. We present here both English version and Finnish version of questionnaire that we used with students (Finnish version translated from English version by Lauri Lahti).

English version of questionnaire:

First name: _____ Last name: _____ Year of birth: _____

All these questions ask about how you work as a member in a group.
Please think about what is your role/position when working in a group of people.
 For example, think about how you feel/ behave when you have to work in a student group at school or when you are doing something together with your friends.

Here you have 24 statements. Please answer how much you agree or disagree with each statement.
 Select one number (1, 2, 3, 4 or 5) that corresponds to your opinion:
1 = "I strongly AGREE", 2="I quite much AGREE", 3="Neutral opinion",
4 ="I quite much DISAGREE", 5 = "I strongly DISAGREE"

"When I work as a member in a group..." ☺ ☹

1) ...I am flexible to tolerate changes	1	2	3	4	5
2) ...I am actively thinking creatively.	1	2	3	4	5
3) ...I am active to create changes.	1	2	3	4	5
4) ...I am active in building and keeping power structures in the group.	1	2	3	4	5
5) ...I am active to negotiate (talk) to reach agreement and commitment.	1	2	3	4	5
6) ...I am actively presenting (telling) new ideas to other people.	1	2	3	4	5
7) ...I make big efforts to get people working productively.	1	2	3	4	5
8) ...I actively try to make working environment productive.	1	2	3	4	5
9) ...I am actively thinking how to use time well.	1	2	3	4	5
10) ...I am actively planning and setting goals (targets).	1	2	3	4	5
11) ...I am actively designing and organizing things.	1	2	3	4	5
12) ...I am efficient in delegating (sharing) work to other people.	1	2	3	4	5
13) ...I am actively thinking how people can best work together.	1	2	3	4	5
14) ...I am actively designing how work should be done.	1	2	3	4	5
15) ...I am actively thinking many different things that belong to current work.	1	2	3	4	5
16) ...I am actively giving attention to my personal performance in group.	1	2	3	4	5
17) ...I am actively giving attention to the performance of the whole group altogether.	1	2	3	4	5
18) ...I am actively giving attention to the performance of each individual person in the group.	1	2	3	4	5
19) ...I am actively building (forming) groups and teams.	1	2	3	4	5
20) ...I actively want to make decisions so that all people in group can agree.	1	2	3	4	5
21) ...I make big efforts to help people to avoid conflicts in group.	1	2	3	4	5
22) ...I actively understand well myself and other people.	1	2	3	4	5
23) ...I actively want to communicate effectively.	1	2	3	4	5
24) ...I actively want to give guidance to other people.	1	2	3	4	5

Finnish version of questionnaire:

Etunimi: _____ Sukunimi: _____ Syntymävuosi: _____

Kaikki nämä kysymykset käsittelevät sitä, miten sinä työskentelet ryhmän jäsenenä. Ajattele, millainen rooli/asema sinulla on, kun työskentelet ihmisten muodostamassa ryhmässä. Esimerkiksi ajattele, millaisia ovat tuntemuksesi/käyttäytymisesi, kun sinun täytyy työskennellä opiskelijaryhmässä koulussa tai kun olet tekemässä jotain yhdessä ystäväsi kanssa.

Tässä sinulla on 24 väittämää. Vastaa, kuinka paljon olet samaa tai eri mieltä kusta kin väittämästä. Valitse yksi numero (1, 2, 3, 4 tai 5), joka täsmää sinun mieli pitee seesi:
1 = "Olen vahvasti SAMAA mieltä", 2 = "Olen melko paljon SAMAA mieltä", 3 = "Neutraali mielipide", 4 = "Olen melko paljon ERI mieltä", 5 = "Olen vahvasti ERI mieltä"

"Kun työskentelet ryhmän jäsenenä, ..."

	☺				☹
1) ...olen joustava sietämään muutoksia.	1	2	3	4	5
2) ...olen ahkera ajattelemaan luovasti.	1	2	3	4	5
3) ...olen ahkera luomaan muutoksia.	1	2	3	4	5
4) ...olen ahkera rakentamaan ja ylläpitämään valtarakenteita ryhmässä.	1	2	3	4	5
5) ...olen ahkera neuvottelemaan (puhumaan), jotta yhteisymmärrys ja omistautuminen voitaisiin saavuttaa.	1	2	3	4	5
6) ...olen ahkera esittelemään (kertomaan) uusia ajatuksia toisille ihmisille.	1	2	3	4	5
7) ...teen suuria ponnisteluja, jotta saisin ihmiset työskentelemään tuottavasti.	1	2	3	4	5
8) ...yrityn ahkerasti tehdä työskentely-ympäristöstä tuottavan.	1	2	3	4	5
9) ...ajattele ahkerasti, kuinka ajan voisi käyttää hyvin.	1	2	3	4	5
10) ...olen ahkera laatimaan aikatauluja ja asettamaan tavoitteita (päämääriä).	1	2	3	4	5
11) ...olen ahkera suunnittelemaan ja järjestämään asioita.	1	2	3	4	5
12) ...olen ahkera välittämään (jakamaan) työtä toisille ihmisille.	1	2	3	4	5
13) ...olen ahkera ajattelemaan, kuinka ihmiset voisivat parhaiten työskennellä yhdessä.	1	2	3	4	5
14) ...olen ahkera suunnittelemaan, miten työ pitäisi tehdä.	1	2	3	4	5
15) ...olen ahkera ajattelemaan useita eri asioita, jotka kuuluvat senhetkiseen työhön.	1	2	3	4	5
16) ...olen ahkera kiinnittämään huomiota henkilökohtaiseen suoritukseen ryhmässä.	1	2	3	4	5
17) ...olen ahkera kiinnittämään huomiota koko ryhmän suoritukseen yhdessä.	1	2	3	4	5
18) ...olen ahkera kiinnittämään huomiota jokaisen yksittäisen henkilön suoritukseen ryhmässä.	1	2	3	4	5
19) ...olen ahkera rakentamaan (muodostamaan) ryhmiä ja joukkueita.	1	2	3	4	5
20) ...haluan ahkerasti tehdä ratkaisuja niin, että kaikki ihmiset ryhmässä voivat olla samaa mieltä.	1	2	3	4	5
21) ...teen suuria ponnisteluja auttaakseni ihmisiä välttämään ristiriitoja ryhmässä.	1	2	3	4	5
22) ...olen ahkera ymmärtämään hyvin itseäni ja muita ihmisiä.	1	2	3	4	5
23) ...haluan ahkerasti viestiä tavalla, joka vaikuttaa.	1	2	3	4	5
24) ...haluan ahkerasti antaa opastusta toisille ihmisille.	1	2	3	4	5

Appendix U

This listing shows for 102 core concepts the highest-ranking hyperlinked concepts based on statistical feature of corresponding Wikipedia articles in respect to hierarchy of hyperlinks (as explained in Subchapter 6.3). Value of “position among hyperlinks departing from Wikipedia article of start concept” indicates for the highest-ranking start concept or end concept what is its ranking position among all start concepts (in natural order of increasing distance from the beginning of the article) of those hyperlinks that arrive to current end concept (N/A = not available).

Observed concept	Ranking based on hierarchy of hyperlinks for observed concept		Observed concept	Ranking based on hierarchy of hyperlinks for observed concept
Concept	End concepts for hyperlinks departing from observed concept (position among hyperlinks)		Concept	Start concepts for hyperlinks arriving to observed concept (position among hyperlinks)
Adolescence	Childhood (1)		Adolescence	Childhood (1)
Adolescence	Child (2)		Adolescence	Child (2)
Adolescence	Television (3)		Adolescence	Education (5)
Adolescence	Sport (4)		Adolescence	Infant (6)
Adolescence	Education (5)		Adolescence	Old_age (7)
Adolescence	Infant (6)		Adolescence	Human (N/A)
Adolescence	Old_age (7)		Adolescence	Dog (N/A)
Animal	Organism (1)		Adolescence	Friendship (N/A)
Animal	Plant (2)		Animal	Plant (2)
Animal	Human (3)		Animal	Human (3)
Animal	Water (4)		Animal	Nature (7)
Animal	Oxygen (5)		Animal	Atmosphere_of_Earth (9)
Animal	Evolution (6)		Animal	Biology (10)
Animal	Nature (7)		Animal	Food (N/A)
Animal	Time (8)		Animal	Birth (N/A)
Animal	Atmosphere_of_Earth (9)		Animal	Eating (N/A)
Animal	Biology (10)		Animal	Friendship (N/A)
Atmosphere_of_Earth	Oxygen (1)		Animal	Pet (N/A)
Atmosphere_of_Earth	Organism (2)		Atmosphere_of_Earth	Nature (5)
Atmosphere_of_Earth	Evolution (3)		Atmosphere_of_Earth	Biology (7)
Atmosphere_of_Earth	Automobile (4)		Atmosphere_of_Earth	Plant (8)
Atmosphere_of_Earth	Nature (5)		Atmosphere_of_Earth	Animal (9)
Atmosphere_of_Earth	Time (6)		Automobile	Oxygen (1)
Atmosphere_of_Earth	Biology (7)		Automobile	City (N/A)
Atmosphere_of_Earth	Plant (8)		Automobile	Atmosphere_of_Earth (N/A)
Atmosphere_of_Earth	Animal (9)		Bed	Dream (3)
Automobile	Oxygen (1)		Biology	Evolution (1)
Bed	Infant (1)		Biology	Organism (2)
Bed	Hospital (2)		Biology	Health (3)
Bed	Dream (3)		Biology	Plant (5)
Biology	Evolution (1)		Biology	Animal (6)
Biology	Organism (2)		Biology	Nature (7)
Biology	Health (3)		Biology	Atmosphere_of_Earth (9)
Biology	Human (4)		Biology	Education (N/A)
Biology	Plant (5)		Biology	Love (N/A)
Biology	Animal (6)		Biology	Old_age (N/A)
Biology	Nature (7)		Biology	Water (N/A)
Biology	Time (8)		Birth	Parent (N/A)
Biology	Atmosphere_of_Earth (9)		Book	Paper (1)
Birth	Animal (1)		Book	Hobby (N/A)
Birth	Mother (2)		Bread	Food (4)
Birth	Sun (3)		Cat	Dog (2)
Birth	Death (4)		Cat	Pet (3)
Book	Paper (1)		Child	Parent (1)
Book	Music (2)		Child	Childhood (2)
Bread	Water (1)		Child	Infant (3)
Bread	Paper (2)		Child	Old_age (4)
Bread	Money (3)		Child	Adolescence (5)
Bread	Food (4)		Child	Family (8)
Cat	Human (1)		Child	Education (N/A)
Cat	Dog (2)		Childhood	Child (1)
Cat	Pet (3)		Childhood	Infant (2)
Child	Parent (1)		Childhood	Old_age (3)
Child	Childhood (2)		Childhood	Adolescence (4)

Child	Infant (3)		Childhood	Human (N/A)
Child	Old_age (4)		Childhood	Education (N/A)
Child	Adolescence (5)		City	Human (N/A)
Child	Sibling (6)		Clock	Time (1)
Child	Marriage (7)		Clock	Future (3)
Child	Family (8)		Clothing	Paper (4)
Child	Leisure (9)		Clothing	Human (N/A)
Childhood	Child (1)		Clothing	Shoe (N/A)
Childhood	Infant (2)		Computer	Clock (N/A)
Childhood	Old_age (3)		Computer	Food (N/A)
Childhood	Adolescence (4)		Death	Disease (2)
City	Automobile (1)		Death	Diet (nutrition) (6)
City	Rain (2)		Death	Future (N/A)
City	Religion (3)		Death	Food (N/A)
Clock	Time (1)		Death	Birth (N/A)
Clock	Computer (2)		Death	Marriage (N/A)
Clock	Future (3)		Death	Old_age (N/A)
Clothing	Religion (1)		Diet (nutrition)	Health (2)
Clothing	Television (2)		Diet (nutrition)	Death (3)
Clothing	Marriage (3)		Diet (nutrition)	Food (N/A)
Clothing	Paper (4)		Diet (nutrition)	Human (N/A)
Computer	Television (1)		Diet (nutrition)	Physical_fitness (N/A)
Computer	Telephone (2)		Disease	Death (1)
Death	Organism (1)		Disease	Health (N/A)
Death	Disease (2)		Disease	Hospital (N/A)
Death	Evolution (3)		Disease	War (N/A)
Death	Heart (4)		Disease	Oxygen (N/A)
Death	Oxygen (5)		Dog	Pet (1)
Death	Diet (nutrition) (6)		Dog	Cat (3)
Death	Physical_fitness (7)		Dream	Bed (2)
Death	Human (8)		Eating	Food (1)
Death	War (9)		Eating	Hobby (N/A)
Diet (nutrition)	Organism (1)		Eating	Leisure (N/A)
Diet (nutrition)	Health (2)		Education	Learning (1)
Diet (nutrition)	Death (3)		Education	Adolescence (4)
Diet (nutrition)	Religion (4)		Education	School (6)
Disease	Death (1)		Education	Teacher (9)
Dog	Pet (1)		Education	Leisure (13)
Dog	Adolescence (2)		Education	Time (N/A)
Dog	Cat (3)		Education	Test (assessment) (N/A)
Dream	God (1)		Education	Hobby (N/A)
Dream	Bed (2)		Education	Peace (N/A)
Eating	Food (1)		Emotion	Sadness (3)
Eating	Animal (2)		Emotion	Happiness (5)
Eating	Organism (3)		Emotion	Love (6)
Eating	Plant (4)		Emotion	Hatred (7)
Eating	Human (5)		Emotion	Pleasure (8)
Education	Learning (1)		Emotion	Human (N/A)
Education	Philosophy (2)		Emotion	Marriage (N/A)
Education	Childhood (3)		Evolution	Biology (1)
Education	Adolescence (4)		Evolution	Organism (2)
Education	Child (5)		Evolution	Human (N/A)
Education	School (6)		Evolution	Nature (N/A)
Education	Human (7)		Evolution	Animal (N/A)
Education	Biology (8)		Evolution	Flower (N/A)
Education	Teacher (9)		Evolution	Future (N/A)
Education	Sibling (10)		Evolution	Religion (N/A)
Education	Marriage (11)		Evolution	Atmosphere_of_Earth (N/A)
Education	Family (12)		Evolution	Death (N/A)
Education	Leisure (13)		Evolution	Emotion (N/A)
Emotion	Experience (1)		Experience	Emotion (N/A)
Emotion	Evolution (2)		Experience	Learning (N/A)
Emotion	Sadness (3)		Experience	World (N/A)
Emotion	Joy (4)		Family	Marriage (1)
Emotion	Happiness (5)		Family	Mother (2)
Emotion	Love (6)		Family	Father (3)
Emotion	Hatred (7)		Family	Sibling (4)
Emotion	Pleasure (8)		Family	Child (5)
Evolution	Biology (1)		Family	Leisure (6)
Evolution	Organism (2)		Family	Human (N/A)
Evolution	Oxygen (3)		Family	Education (N/A)
Evolution	Plant (4)		Family	Love (N/A)
Evolution	Philosophy (5)		Family	Home (N/A)
Experience	Time (1)		Family	House (N/A)
Experience	Philosophy (2)		Family	Party (N/A)

Family	Marriage (1)		Father	Parent (1)
Family	Mother (2)		Father	Mother (2)
Family	Father (3)		Father	Family (4)
Family	Sibling (4)		Father	Sibling (5)
Family	Child (5)		Father	God (N/A)
Family	Leisure (6)		Flower	Plant (2)
Father	Parent (1)		Flower	Forest (N/A)
Father	Mother (2)		Food	Eating (1)
Father	Marriage (3)		Food	Bread (4)
Father	Family (4)		Food	Health (10)
Father	Sibling (5)		Food	Hobby (N/A)
Father	Love (6)		Food	Money (N/A)
Flower	Evolution (1)		Forest	Tree (1)
Flower	Plant (2)		Forest	Plant (4)
Food	Eating (1)		Friendship	Love (3)
Food	Animal (2)		Future	Time (1)
Food	Plant (3)		Future	Clock (7)
Food	Bread (4)		Goal	Purpose (1)
Food	Water (5)		Goal	Teacher (N/A)
Food	War (6)		God	Religion (1)
Food	School (7)		God	Philosophy (2)
Food	Computer (8)		God	Time (N/A)
Food	Diet (nutrition) (9)		God	Human (N/A)
Food	Health (10)		God	Dream (N/A)
Food	Death (11)		God	Marriage (N/A)
Food	Human (12)		God	Purpose (N/A)
Forest	Tree (1)		Happiness	Emotion (1)
Forest	Flower (2)		Happiness	Joy (2)
Forest	Rain (3)		Happiness	Human (N/A)
Forest	Plant (4)		Happiness	Pleasure (N/A)
Friendship	Philosophy (1)		Happiness	Purpose (N/A)
Friendship	Adolescence (2)		Happiness	Hatred (N/A)
Friendship	Love (3)		Happiness	Love (N/A)
Friendship	Animal (4)		Happiness	Sadness (N/A)
Future	Time (1)		Hatred	Emotion (1)
Future	Philosophy (2)		Hatred	Pleasure (2)
Future	Human (3)		Hatred	Love (4)
Future	Evolution (4)		Hatred	Sadness (5)
Future	Religion (5)		Hatred	War (N/A)
Future	Death (6)		Health	Physical fitness (2)
Future	Clock (7)		Health	Diet (nutrition) (3)
Goal	Purpose (1)		Health	Food (4)
God	Religion (1)		Health	Biology (5)
God	Philosophy (2)		Health	Human (N/A)
God	Father (3)		Health	Infant (N/A)
God	Nature (4)		Health	Hospital (N/A)
Ground	Philosophy (1)		Heart	Oxygen (N/A)
Happiness	Emotion (1)		Heart	Death (N/A)
Happiness	Joy (2)		Heart	Organism (N/A)
Hatred	Emotion (1)		Home	House (2)
Hatred	Pleasure (2)		Hospital	Bed (N/A)
Hatred	Happiness (3)		Hospital	Infant (N/A)
Hatred	Love (4)		House	Home (2)
Hatred	Sadness (5)		House	Human (N/A)
Health	Disease (1)		House	Hobby (N/A)
Health	Physical fitness (2)		Human	Animal (9)
Health	Diet (nutrition) (3)		Human	Religion (12)
Health	Food (4)		Human	World (N/A)
Health	Biology (5)		Human	People (N/A)
Hobby	Leisure (1)		Human	Nature (N/A)
Hobby	Sport (2)		Human	Food (N/A)
Hobby	Book (3)		Human	Biology (N/A)
Hobby	Education (4)		Human	Death (N/A)
Hobby	Food (5)		Human	Water (N/A)
Hobby	Eating (6)		Human	Eating (N/A)
Hobby	Plant (7)		Human	Future (N/A)
Hobby	House (8)		Human	Parent (N/A)
Home	Family (1)		Human	Mother (N/A)
Home	House (2)		Human	Education (N/A)
Home	Love (3)		Human	Cat (N/A)
Hospital	Disease (1)		Infant	Child (1)
Hospital	Health (2)		Infant	Old age (4)
House	Family (1)		Infant	Childhood (5)
House	Home (2)		Infant	Adolescence (6)
House	Television (3)		Infant	Bed (N/A)

House	Pet (4)	Joy	Happiness (1)
Human	City (1)	Joy	Emotion (N/A)
Human	Diet (nutrition) (2)	Learning	Education (2)
Human	Childhood (3)	Learning	Teacher (N/A)
Human	Adolescence (4)	Leisure	Education (4)
Human	Old_age (5)	Leisure	Marriage (7)
Human	Emotion (6)	Leisure	Family (8)
Human	Love (7)	Leisure	Hobby (N/A)
Human	Evolution (8)	Leisure	Child (N/A)
Human	Animal (9)	Leisure	Mother (N/A)
Human	Family (10)	Light	Time (1)
Human	Philosophy (11)	Light	Plant (N/A)
Human	Religion (12)	Love	Emotion (2)
Human	Clothing (13)	Love	Pleasure (3)
Human	House (14)	Love	Hatred (5)
Human	Oxygen (15)	Love	Sadness (6)
Human	Happiness (16)	Love	Friendship (7)
Human	Health (17)	Love	Marriage (11)
Human	War (18)	Love	Human (N/A)
Human	God (19)	Love	Mother (N/A)
Human	Music (20)	Love	Father (N/A)
Infant	Child (1)	Love	Home (N/A)
Infant	Hospital (2)	Love	Sibling (N/A)
Infant	Health (3)	Marriage	Family (2)
Infant	Old_age (4)	Marriage	Love (3)
Infant	Childhood (5)	Marriage	Sibling (7)
Infant	Adolescence (6)	Marriage	Leisure (8)
Joy	Happiness (1)	Marriage	Child (N/A)
Learning	Experience (1)	Marriage	Education (N/A)
Learning	Education (2)	Marriage	Mother (N/A)
Learning	Time (3)	Marriage	Father (N/A)
Learning	Physical_fitness (4)	Marriage	Clothing (N/A)
Leisure	Time (1)	Money	Bread (N/A)
Leisure	Work (2)	Mother	Parent (1)
Leisure	Eating (3)	Mother	Father (3)
Leisure	Education (4)	Mother	Family (4)
Leisure	Television (5)	Mother	Sibling (5)
Leisure	Sibling (6)	Mother	Birth (N/A)
Leisure	Marriage (7)	Music	Human (N/A)
Leisure	Family (8)	Music	Book (N/A)
Light	Time (1)	Music	Pleasure (N/A)
Light	Sun (2)	Music	Party (N/A)
Light	Television (3)	Music	Philosophy (N/A)
Love	Family (1)	Music	Test (assessment) (N/A)
Love	Emotion (2)	Nature	Plant (5)
Love	Pleasure (3)	Nature	Animal (6)
Love	Happiness (4)	Nature	Biology (8)
Love	Hatred (5)	Nature	Atmosphere_of_Earth (10)
Love	Sadness (6)	Nature	God (N/A)
Love	Friendship (7)	Old_age	Infant (3)
Love	Philosophy (8)	Old_age	Child (4)
Love	Religion (9)	Old_age	Childhood (5)
Love	Biology (10)	Old_age	Adolescence (6)
Love	Marriage (11)	Old_age	Human (N/A)
Marriage	Religion (1)	Organism	Biology (1)
Marriage	Family (2)	Organism	Evolution (2)
Marriage	Love (3)	Organism	Plant (4)
Marriage	God (4)	Organism	Animal (N/A)
Marriage	Emotion (5)	Organism	Atmosphere_of_Earth (N/A)
Marriage	Death (6)	Organism	Nature (N/A)
Marriage	Sibling (7)	Organism	Death (N/A)
Marriage	Leisure (8)	Organism	Diet (nutrition) (N/A)
Money	Water (1)	Organism	Eating (N/A)
Money	Food (2)	Organism	Water (N/A)
Mother	Parent (1)	Oxygen	Plant (1)
Mother	Human (2)	Oxygen	Automobile (2)
Mother	Father (3)	Oxygen	Sun (3)
Mother	Family (4)	Oxygen	Water (9)
Mother	Sibling (5)	Oxygen	Atmosphere_of_Earth (N/A)
Mother	Marriage (6)	Oxygen	Nature (N/A)
Mother	Love (7)	Oxygen	Animal (N/A)
Mother	Leisure (8)	Oxygen	Evolution (N/A)
Music	Religion (1)	Oxygen	Human (N/A)
Music	Time (2)	Oxygen	Death (N/A)
Music	Television (3)	Oxygen	Tree (N/A)

Nature	Human (1)		Paper	Book (1)
Nature	Sun (2)		Paper	Clothing (2)
Nature	Oxygen (3)		Paper	Pen (N/A)
Nature	Organism (4)		Paper	Bread (N/A)
Nature	Plant (5)		Parent	Father (1)
Nature	Animal (6)		Parent	Mother (2)
Nature	Evolution (7)		Parent	Child (5)
Nature	Biology (8)		Parent	Sibling (6)
Nature	Time (9)		Peace	War (2)
Nature	Atmosphere of Earth (10)		People	Pet (N/A)
Old_age	Biology (1)		Pet	Dog (2)
Old_age	Death (2)		Pet	Cat (3)
Old_age	Infant (3)		Pet	House (N/A)
Old_age	Child (4)		Philosophy	Religion (1)
Old_age	Childhood (5)		Philosophy	God (2)
Old_age	Adolescence (6)		Philosophy	Human (N/A)
Organism	Biology (1)		Philosophy	Experience (N/A)
Organism	Evolution (2)		Philosophy	Time (N/A)
Organism	Heart (3)		Philosophy	People (N/A)
Organism	Plant (4)		Philosophy	Education (N/A)
Oxygen	Plant (1)		Philosophy	Future (N/A)
Oxygen	Automobile (2)		Philosophy	Love (N/A)
Oxygen	Sun (3)		Philosophy	Friendship (N/A)
Oxygen	Philosophy (4)		Philosophy	Ground (N/A)
Oxygen	Heart (5)		Philosophy	Pleasure (N/A)
Oxygen	Disease (6)		Philosophy	Purpose (N/A)
Oxygen	Sport (7)		Philosophy	Evolution (N/A)
Oxygen	Rain (8)		Philosophy	Oxygen (N/A)
Oxygen	Water (9)		Philosophy	Test (assessment) (N/A)
Paper	Book (1)		Physical fitness	Health (1)
Paper	Clothing (2)		Physical_fitness	Death (N/A)
Parent	Father (1)		Physical_fitness	Learning (N/A)
Parent	Mother (2)		Plant	Organism (1)
Parent	Birth (3)		Plant	Animal (3)
Parent	Human (4)		Plant	Water (5)
Parent	Child (5)		Plant	Oxygen (6)
Parent	Sibling (6)		Plant	Forest (7)
Party	Music (1)		Plant	Flower (8)
Party	Television (2)		Plant	Nature (9)
Party	Family (3)		Plant	Atmosphere of Earth (11)
Peace	Education (1)		Plant	Biology (12)
Peace	War (2)		Plant	Food (N/A)
Pen	Paper (1)		Plant	Evolution (N/A)
People	Human (1)		Plant	Eating (N/A)
People	Philosophy (2)		Plant	Hobby (N/A)
People	Religion (3)		Plant	Rain (N/A)
People	Purpose (4)		Plant	Summer (N/A)
Pet	Animal (1)		Plant	Sun (N/A)
Pet	Dog (2)		Pleasure	Emotion (1)
Pet	Cat (3)		Pleasure	Hatred (3)
Pet	People (4)		Pleasure	Love (4)
Philosophy	Religion (1)		Pleasure	Sadness (5)
Philosophy	God (2)		Purpose	Goal (1)
Philosophy	Music (3)		Purpose	People (N/A)
Physical_fitness	Health (1)		Rain	Water (1)
Physical_fitness	Diet (nutrition) (2)		Rain	City (N/A)
Plant	Organism (1)		Rain	Forest (N/A)
Plant	Tree (2)		Rain	Oxygen (N/A)
Plant	Animal (3)		Religion	Philosophy (1)
Plant	Light (4)		Religion	God (2)
Plant	Water (5)		Religion	Human (5)
Plant	Oxygen (6)		Religion	People (N/A)
Plant	Forest (7)		Religion	War (N/A)
Plant	Flower (8)		Religion	Future (N/A)
Plant	Nature (9)		Religion	Time (N/A)
Plant	Time (10)		Religion	City (N/A)
Plant	Atmosphere of Earth (11)		Religion	Clothing (N/A)
Plant	Biology (12)		Religion	Diet (nutrition) (N/A)
Pleasure	Emotion (1)		Religion	Love (N/A)
Pleasure	Happiness (2)		Religion	Marriage (N/A)
Pleasure	Hatred (3)		Religion	Music (N/A)
Pleasure	Love (4)		Sadness	Emotion (1)
Pleasure	Sadness (5)		Sadness	Pleasure (2)
Pleasure	Music (6)		Sadness	Hatred (4)
Pleasure	Philosophy (7)		Sadness	Love (5)

Purpose	Goal (1)		Sadness	Sorrow (6)
Purpose	Philosophy (2)		School	Teacher (1)
Purpose	God (3)		School	Education (2)
Purpose	Happiness (4)		School	Food (N/A)
Rain	Water (1)		Sea	Water (1)
Rain	Plant (2)		Sibling	Parent (1)
Rain	Sun (3)		Sibling	Family (3)
Religion	Philosophy (1)		Sibling	Mother (4)
Religion	God (2)		Sibling	Father (5)
Religion	Sun (3)		Sibling	Marriage (6)
Religion	Evolution (4)		Sibling	Child (N/A)
Religion	Human (5)		Sibling	Education (N/A)
Sadness	Emotion (1)		Sibling	Leisure (N/A)
Sadness	Pleasure (2)		Sorrow	Sadness (1)
Sadness	Happiness (3)		Sport	Adolescence (N/A)
Sadness	Hatred (4)		Sport	Hobby (N/A)
Sadness	Love (5)		Sport	Oxygen (N/A)
Sadness	Sorrow (6)		Sun	Oxygen (1)
School	Teacher (1)		Sun	Light (N/A)
School	Education (2)		Sun	Water (N/A)
Sea	Water (1)		Sun	Nature (N/A)
Shoe	Clothing (1)		Sun	Birth (N/A)
Sibling	Parent (1)		Sun	Rain (N/A)
Sibling	Love (2)		Sun	Religion (N/A)
Sibling	Family (3)		Teacher	Education (1)
Sibling	Mother (4)		Teacher	School (2)
Sibling	Father (5)		Teacher	Test (assessment) (N/A)
Sibling	Marriage (6)		Telephone	Computer (N/A)
Sorrow	Sadness (1)		Television	Time (N/A)
Sport	Television (1)		Television	Music (N/A)
Summer	Plant (1)		Television	Adolescence (N/A)
Sun	Oxygen (1)		Television	Clothing (N/A)
Sun	Plant (2)		Television	Computer (N/A)
Teacher	Education (1)		Television	House (N/A)
Teacher	School (2)		Television	Leisure (N/A)
Teacher	Goal (3)		Television	Light (N/A)
Teacher	Learning (4)		Television	Party (N/A)
Test (assessment)	Education (1)		Television	Sport (N/A)
Test (assessment)	Philosophy (2)		Time	Clock (3)
Test (assessment)	Music (3)		Time	Future (5)
Test (assessment)	Teacher (4)		Time	Light (6)
Time	Religion (1)		Time	Experience (N/A)
Time	Philosophy (2)		Time	Nature (N/A)
Time	Clock (3)		Time	Plant (N/A)
Time	God (4)		Time	Water (N/A)
Time	Future (5)		Time	Animal (N/A)
Time	Light (6)		Time	Atmosphere_of_Earth (N/A)
Time	Education (7)		Time	Biology (N/A)
Time	Television (8)		Time	Learning (N/A)
Tree	Oxygen (1)		Time	Leisure (N/A)
Tree	Forest (2)		Time	Music (N/A)
Tree	Water (3)		Travel	Water (N/A)
War	Hatred (1)		Tree	Forest (2)
War	Religion (2)		Tree	Plant (N/A)
War	Disease (3)		War	Peace (4)
War	Peace (4)		War	Human (N/A)
Water	Sea (1)		War	Death (N/A)
Water	Human (2)		War	Food (N/A)
Water	Rain (3)		Water	Sea (1)
Water	Oxygen (4)		Water	Rain (3)
Water	Organism (5)		Water	Oxygen (4)
Water	Sun (6)		Water	Plant (7)
Water	Plant (7)		Water	Food (N/A)
Water	Travel (8)		Water	Animal (N/A)
Water	Biology (9)		Water	Bread (N/A)
Water	Time (10)		Water	Money (N/A)
World	Human (1)		Water	Tree (N/A)
World	Experience (2)		Work	Leisure (N/A)

Appendix V

This listing shows the highest-ranking hyperlinked concepts based on statistical feature of corresponding Wikipedia articles in respect to repetition of hyperlink terms (as explained in Subchapter 6.3).

Observed concept	Ranking based on repetition of hyperlink terms for observed concept		Observed concept	Ranking based on repetition of hyperlink terms for observed concept
Concept	End concepts for hyperlinks departing from observed concept (repetitions of hyperlink terms)		Concept	Start concepts for hyperlinks arriving to observed concept (repetitions of hyperlink terms)
Adolescence	Child (14)		Adolescence	Child (14)
Adolescence	Old_age (5)		Adolescence	Human (7)
Adolescence	Education (4)		Adolescence	Old_age (5)
Adolescence	Childhood (3)		Adolescence	Education (4)
Adolescence	Sport (1)		Adolescence	Childhood (3)
Adolescence	Television (1)		Adolescence	Dog (0)
Adolescence	Infant (0)		Adolescence	Friendship (0)
Animal	Plant (10)		Adolescence	Infant (0)
Animal	Evolution (8)		Animal	Plant (10)
Animal	Organism (8)		Animal	Biology (5)
Animal	Biology (5)		Animal	Food (2)
Animal	Water (3)		Animal	Human (2)
Animal	Human (2)		Animal	Atmosphere_of_Earth (0)
Animal	Time (2)		Animal	Birth (0)
Animal	Oxygen (1)		Animal	Eating (0)
Animal	Atmosphere_of_Earth (0)		Animal	Friendship (0)
Animal	Nature (0)		Animal	Nature (0)
Atmosphere_of_Earth	Oxygen (17)		Animal	Pet (0)
Atmosphere_of_Earth	Plant (4)		Atmosphere_of_Earth	Plant (4)
Atmosphere_of_Earth	Time (4)		Atmosphere_of_Earth	Animal (2)
Atmosphere_of_Earth	Evolution (3)		Atmosphere_of_Earth	Biology (0)
Atmosphere_of_Earth	Animal (2)		Atmosphere_of_Earth	Nature (0)
Atmosphere_of_Earth	Automobile (1)		Automobile	City (4)
Atmosphere_of_Earth	Organism (1)		Automobile	Oxygen (2)
Atmosphere_of_Earth	Biology (0)		Automobile	Atmosphere_of_Earth (0)
Atmosphere_of_Earth	Nature (0)		Bed	Dream (0)
Automobile	Oxygen (2)		Biology	Organism (57)
Bed	Hospital (4)		Biology	Evolution (24)
Bed	Infant (2)		Biology	Animal (14)
Bed	Dream (0)		Biology	Plant (9)
Biology	Organism (57)		Biology	Atmosphere_of_Earth (2)
Biology	Evolution (24)		Biology	Health (1)
Biology	Animal (14)		Biology	Nature (1)
Biology	Plant (9)		Biology	Education (0)
Biology	Human (8)		Biology	Love (0)
Biology	Time (3)		Biology	Old_age (0)
Biology	Atmosphere_of_Earth (2)		Biology	Water (0)
Biology	Health (1)		Birth	Parent (1)
Biology	Nature (1)		Book	Paper (31)
Birth	Mother (5)		Book	Hobby (0)
Birth	Death (2)		Bread	Food (17)
Birth	Animal (1)		Cat	Pet (22)
Birth	Sun (1)		Cat	Dog (20)
Book	Paper (31)		Child	Childhood (3)
Book	Music (0)		Child	Parent (2)
Bread	Water (20)		Child	Old_age (1)
Bread	Food (17)		Child	Adolescence (0)
Bread	Money (2)		Child	Education (0)
Bread	Paper (1)		Child	Family (0)
Cat	Human (62)		Child	Infant (0)
Cat	Pet (22)		Childhood	Child (26)
Cat	Dog (20)		Childhood	Human (1)
Child	Childhood (3)		Childhood	Adolescence (0)
Child	Parent (2)		Childhood	Education (0)
Child	Old_age (1)		Childhood	Infant (0)
Child	Adolescence (0)		Childhood	Old_age (0)
Child	Family (0)		City	Human (1)
Child	Infant (0)		Clock	Time (79)

Child	Leisure (0)		Clock	Future (0)
Child	Marriage (0)		Clothing	Human (10)
Child	Sibling (0)		Clothing	Paper (2)
Childhood	Child (26)		Clothing	Shoe (0)
Childhood	Adolescence (0)		Computer	Clock (0)
Childhood	Infant (0)		Computer	Food (0)
Childhood	Old_age (0)		Death	Disease (14)
City	Automobile (2)		Death	Future (5)
City	Religion (1)		Death	Diet_(nutrition) (2)
City	Rain (0)		Death	Food (2)
Clock	Time (79)		Death	Birth (0)
Clock	Computer (8)		Death	Marriage (0)
Clock	Future (0)		Death	Old_age (0)
Clothing	Paper (2)		Diet_(nutrition)	Food (17)
Clothing	Religion (2)		Diet_(nutrition)	Health (4)
Clothing	Television (1)		Diet_(nutrition)	Human (1)
Clothing	Marriage (0)		Diet_(nutrition)	Death (0)
Computer	Telephone (1)		Diet_(nutrition)	Physical_fitness (0)
Computer	Television (1)		Disease	Health (8)
Death	Disease (14)		Disease	Death (1)
Death	Human (13)		Disease	Hospital (1)
Death	Organism (13)		Disease	War (1)
Death	Evolution (7)		Disease	Oxygen (0)
Death	Oxygen (3)		Dog	Pet (19)
Death	Diet_(nutrition) (2)		Dog	Cat (9)
Death	Heart (2)		Dream	Bed (1)
Death	Physical_fitness (1)		Eating	Food (14)
Death	War (0)		Eating	Hobby (0)
Diet_(nutrition)	Health (4)		Eating	Leisure (0)
Diet_(nutrition)	Religion (2)		Education	Learning (48)
Diet_(nutrition)	Organism (1)		Education	School (34)
Diet_(nutrition)	Death (0)		Education	Teacher (8)
Disease	Death (1)		Education	Time (4)
Dog	Pet (19)		Education	Adolescence (2)
Dog	Cat (9)		Education	Leisure (1)
Dog	Adolescence (1)		Education	Test_(assessment) (1)
Dream	Bed (1)		Education	Hobby (0)
Dream	God (1)		Education	Peace (0)
Eating	Food (14)		Emotion	Human (15)
Eating	Animal (4)		Emotion	Sadness (9)
Eating	Human (2)		Emotion	Happiness (7)
Eating	Organism (1)		Emotion	Love (6)
Eating	Plant (1)		Emotion	Hatred (1)
Education	Learning (48)		Emotion	Marriage (1)
Education	School (34)		Emotion	Pleasure (1)
Education	Child (13)		Evolution	Organism (75)
Education	Philosophy (10)		Evolution	Human (28)
Education	Human (9)		Evolution	Biology (22)
Education	Teacher (8)		Evolution	Nature (20)
Education	Family (6)		Evolution	Animal (19)
Education	Adolescence (2)		Evolution	Flower (3)
Education	Childhood (2)		Evolution	Future (3)
Education	Biology (1)		Evolution	Religion (3)
Education	Leisure (1)		Evolution	Atmosphere_of_Earth (1)
Education	Marriage (1)		Evolution	Death (1)
Education	Sibling (0)		Evolution	Emotion (0)
Emotion	Experience (12)		Experience	Emotion (1)
Emotion	Sadness (9)		Experience	Learning (0)
Emotion	Happiness (7)		Experience	World (0)
Emotion	Love (6)		Family	Child (51)
Emotion	Hatred (1)		Family	Mother (13)
Emotion	Joy (1)		Family	Marriage (12)
Emotion	Pleasure (1)		Family	Father (8)
Emotion	Evolution (0)		Family	Human (5)
Evolution	Organism (75)		Family	Sibling (4)
Evolution	Plant (32)		Family	Education (3)
Evolution	Biology (22)		Family	Love (2)
Evolution	Philosophy (3)		Family	Home (1)
Evolution	Oxygen (1)		Family	Leisure (1)
Experience	Philosophy (2)		Family	House (0)
Experience	Time (1)		Family	Party (0)
Family	Child (51)		Father	Family (12)
Family	Mother (13)		Father	Mother (8)
Family	Marriage (12)		Father	Parent (4)
Family	Father (8)		Father	Sibling (1)

Family	Sibling (4)		Father	God (0)
Family	Leisure (1)		Flower	Plant (63)
Father	Family (12)		Flower	Forest (0)
Father	Mother (8)		Food	Health (19)
Father	Parent (4)		Food	Eating (3)
Father	Marriage (2)		Food	Bread (1)
Father	Sibling (1)		Food	Hobby (0)
Father	Love (0)		Food	Money (0)
Flower	Plant (63)		Forest	Tree (33)
Flower	Evolution (11)		Forest	Plant (6)
Food	Animal (30)		Friendship	Love (14)
Food	Health (19)		Future	Time (10)
Food	Diet (nutrition) (16)		Future	Clock (0)
Food	Plant (14)		Goal	Purpose (1)
Food	Human (13)		Goal	Teacher (0)
Food	Water (5)		God	Religion (20)
Food	Eating (3)		God	Philosophy (9)
Food	War (2)		God	Time (4)
Food	Bread (1)		God	Human (2)
Food	Computer (1)		God	Dream (0)
Food	Death (1)		God	Marriage (0)
Food	School (1)		God	Purpose (0)
Forest	Tree (33)		Happiness	Emotion (8)
Forest	Plant (6)		Happiness	Human (5)
Forest	Rain (5)		Happiness	Pleasure (4)
Forest	Flower (0)		Happiness	Purpose (2)
Friendship	Love (14)		Happiness	Joy (1)
Friendship	Animal (7)		Happiness	Hatred (0)
Friendship	Philosophy (2)		Happiness	Love (0)
Friendship	Adolescence (0)		Happiness	Sadness (0)
Future	Time (10)		Hatred	Emotion (0)
Future	Human (4)		Hatred	Love (0)
Future	Evolution (2)		Hatred	Pleasure (0)
Future	Religion (2)		Hatred	Sadness (0)
Future	Death (1)		Hatred	War (0)
Future	Philosophy (1)		Health	Physical fitness (10)
Future	Clock (0)		Health	Food (9)
Goal	Purpose (1)		Health	Human (8)
God	Religion (20)		Health	Diet (nutrition) (6)
God	Nature (9)		Health	Biology (2)
God	Philosophy (9)		Health	Infant (1)
God	Father (1)		Health	Hospital (0)
Ground	Philosophy (1)		Heart	Oxygen (2)
Happiness	Emotion (8)		Heart	Death (1)
Happiness	Joy (1)		Heart	Organism (0)
Hatred	Emotion (0)		Home	House (1)
Hatred	Happiness (0)		Hospital	Bed (3)
Hatred	Love (0)		Hospital	Infant (0)
Hatred	Pleasure (0)		House	Home (12)
Hatred	Sadness (0)		House	Human (8)
Health	Disease (15)		House	Hobby (0)
Health	Physical fitness (10)		Human	World (54)
Health	Food (9)		Human	Religion (46)
Health	Diet (nutrition) (6)		Human	People (38)
Health	Biology (2)		Human	Nature (35)
Hobby	Sport (6)		Human	Food (30)
Hobby	Education (4)		Human	Animal (29)
Hobby	Food (3)		Human	Biology (20)
Hobby	Plant (3)		Human	Death (11)
Hobby	Book (1)		Human	Water (6)
Hobby	Eating (1)		Human	Eating (5)
Hobby	House (0)		Human	Future (4)
Hobby	Leisure (0)		Human	Parent (4)
Home	Family (1)		Human	Mother (3)
Home	House (1)		Human	Education (1)
Home	Love (1)		Human	Cat (0)
Hospital	Health (15)		Infant	Child (18)
Hospital	Disease (2)		Infant	Bed (1)
House	Home (12)		Infant	Childhood (1)
House	Family (7)		Infant	Old age (1)
House	Pet (1)		Infant	Adolescence (0)
House	Television (1)		Joy	Emotion (1)
Human	Evolution (72)		Joy	Happiness (1)
Human	Religion (46)		Learning	Education (5)
Human	Emotion (35)		Learning	Teacher (1)

Human	War (35)		Leisure	Education (3)
Human	Animal (29)		Leisure	Family (2)
Human	Diet (nutrition) (29)		Leisure	Hobby (2)
Human	Philosophy (28)		Leisure	Child (1)
Human	Music (22)		Leisure	Marriage (1)
Human	Health (15)		Leisure	Mother (1)
Human	Family (12)		Light	Time (11)
Human	Old_age (11)		Light	Plant (0)
Human	Love (10)		Love	Human (13)
Human	House (9)		Love	Friendship (8)
Human	City (8)		Love	Emotion (4)
Human	Childhood (5)		Love	Mother (4)
Human	God (5)		Love	Pleasure (3)
Human	Adolescence (4)		Love	Hatred (1)
Human	Clothing (4)		Love	Marriage (1)
Human	Happiness (4)		Love	Sadness (1)
Human	Oxygen (1)		Love	Father (0)
Infant	Child (18)		Love	Home (0)
Infant	Health (8)		Love	Sibling (0)
Infant	Childhood (1)		Marriage	Family (38)
Infant	Hospital (1)		Marriage	Child (23)
Infant	Old_age (1)		Marriage	Education (4)
Infant	Adolescence (0)		Marriage	Love (4)
Joy	Happiness (1)		Marriage	Mother (4)
Learning	Time (6)		Marriage	Father (2)
Learning	Education (5)		Marriage	Leisure (1)
Learning	Experience (5)		Marriage	Sibling (1)
Learning	Physical fitness (1)		Marriage	Clothing (0)
Leisure	Time (22)		Money	Bread (0)
Leisure	Work (13)		Mother	Father (3)
Leisure	Education (3)		Mother	Family (2)
Leisure	Family (2)		Mother	Parent (2)
Leisure	Eating (1)		Mother	Birth (1)
Leisure	Marriage (1)		Mother	Sibling (0)
Leisure	Television (1)		Music	Human (7)
Leisure	Sibling (0)		Music	Book (5)
Light	Time (11)		Music	Pleasure (2)
Light	Sun (7)		Music	Party (0)
Light	Television (2)		Music	Philosophy (0)
Love	Friendship (8)		Music	Test (assessment) (0)
Love	Family (6)		Nature	Plant (31)
Love	Emotion (4)		Nature	Animal (25)
Love	Biology (3)		Nature	Atmosphere_of_Earth (17)
Love	Pleasure (3)		Nature	Biology (2)
Love	Religion (3)		Nature	God (0)
Love	Happiness (2)		Old_age	Human (2)
Love	Hatred (1)		Old_age	Child (1)
Love	Marriage (1)		Old_age	Adolescence (0)
Love	Philosophy (1)		Old_age	Childhood (0)
Love	Sadness (1)		Old_age	Infant (0)
Marriage	Family (38)		Organism	Animal (15)
Marriage	Religion (14)		Organism	Plant (12)
Marriage	Death (5)		Organism	Evolution (10)
Marriage	God (5)		Organism	Biology (6)
Marriage	Love (4)		Organism	Atmosphere_of_Earth (1)
Marriage	Leisure (1)		Organism	Nature (1)
Marriage	Sibling (1)		Organism	Death (0)
Marriage	Emotion (0)		Organism	Diet (nutrition) (0)
Money	Water (2)		Organism	Eating (0)
Money	Food (1)		Organism	Water (0)
Mother	Father (3)		Oxygen	Water (41)
Mother	Family (2)		Oxygen	Atmosphere_of_Earth (19)
Mother	Parent (2)		Oxygen	Plant (11)
Mother	Human (1)		Oxygen	Nature (8)
Mother	Leisure (0)		Oxygen	Animal (6)
Mother	Love (0)		Oxygen	Evolution (6)
Mother	Marriage (0)		Oxygen	Human (3)
Mother	Sibling (0)		Oxygen	Automobile (1)
Music	Time (10)		Oxygen	Death (1)
Music	Television (1)		Oxygen	Sun (0)
Music	Religion (0)		Oxygen	Tree (0)
Nature	Human (39)		Paper	Book (9)
Nature	Plant (31)		Paper	Clothing (1)
Nature	Animal (25)		Paper	Pen (1)
Nature	Atmosphere_of_Earth (17)		Paper	Bread (0)

Nature	Organism (11)		Parent	Mother (24)
Nature	Time (7)		Parent	Father (11)
Nature	Evolution (5)		Parent	Child (10)
Nature	Oxygen (4)		Parent	Sibling (2)
Nature	Sun (4)		Peace	War (8)
Nature	Biology (2)		People	Pet (0)
Old_age	Biology (1)		Pet	Cat (20)
Old_age	Child (1)		Pet	Dog (18)
Old_age	Adolescence (0)		Pet	House (0)
Old_age	Childhood (0)		Philosophy	Human (23)
Old_age	Death (0)		Philosophy	Experience (10)
Old_age	Infant (0)		Philosophy	Time (10)
Organism	Plant (12)		Philosophy	People (9)
Organism	Evolution (10)		Philosophy	Religion (7)
Organism	Biology (6)		Philosophy	Education (3)
Organism	Heart (1)		Philosophy	Future (3)
Oxygen	Water (41)		Philosophy	God (3)
Oxygen	Plant (11)		Philosophy	Love (2)
Oxygen	Heart (2)		Philosophy	Friendship (1)
Oxygen	Automobile (1)		Philosophy	Ground (1)
Oxygen	Disease (1)		Philosophy	Pleasure (1)
Oxygen	Philosophy (1)		Philosophy	Purpose (1)
Oxygen	Rain (1)		Philosophy	Evolution (0)
Oxygen	Sport (1)		Philosophy	Oxygen (0)
Oxygen	Sun (0)		Philosophy	Test_(assessment) (0)
Paper	Book (9)		Physical_fitness	Health (3)
Paper	Clothing (1)		Physical_fitness	Death (0)
Parent	Mother (24)		Physical_fitness	Learning (0)
Parent	Father (11)		Plant	Food (13)
Parent	Child (10)		Plant	Animal (12)
Parent	Human (4)		Plant	Water (10)
Parent	Birth (2)		Plant	Biology (8)
Parent	Sibling (2)		Plant	Evolution (7)
Party	Music (7)		Plant	Organism (7)
Party	Family (3)		Plant	Flower (6)
Party	Television (2)		Plant	Forest (6)
Peace	War (8)		Plant	Atmosphere_of_Earth (4)
Peace	Education (1)		Plant	Oxygen (4)
Pen	Paper (3)		Plant	Nature (2)
People	Human (5)		Plant	Eating (1)
People	Philosophy (4)		Plant	Hobby (0)
People	Religion (3)		Plant	Rain (0)
People	Purpose (2)		Plant	Summer (0)
Pet	Animal (40)		Plant	Sun (0)
Pet	Cat (20)		Pleasure	Love (2)
Pet	Dog (18)		Pleasure	Emotion (0)
Pet	People (11)		Pleasure	Hatred (0)
Philosophy	Religion (7)		Pleasure	Sadness (0)
Philosophy	God (3)		Purpose	Goal (5)
Philosophy	Music (2)		Purpose	People (5)
Physical_fitness	Health (3)		Rain	Water (14)
Physical_fitness	Diet_(nutrition) (1)		Rain	City (2)
Plant	Tree (16)		Rain	Forest (0)
Plant	Animal (12)		Rain	Oxygen (0)
Plant	Water (10)		Religion	God (18)
Plant	Biology (8)		Religion	Philosophy (16)
Plant	Organism (7)		Religion	Human (12)
Plant	Flower (6)		Religion	People (12)
Plant	Forest (6)		Religion	War (2)
Plant	Atmosphere_of_Earth (4)		Religion	Future (1)
Plant	Light (4)		Religion	Time (1)
Plant	Oxygen (4)		Religion	City (0)
Plant	Nature (2)		Religion	Clothing (0)
Plant	Time (1)		Religion	Diet_(nutrition) (0)
Pleasure	Philosophy (3)		Religion	Love (0)
Pleasure	Love (2)		Religion	Marriage (0)
Pleasure	Happiness (1)		Religion	Music (0)
Pleasure	Music (1)		Sadness	Emotion (3)
Pleasure	Emotion (0)		Sadness	Sorrow (1)
Pleasure	Hatred (0)		Sadness	Hatred (0)
Pleasure	Sadness (0)		Sadness	Love (0)
Purpose	Happiness (8)		Sadness	Pleasure (0)
Purpose	Philosophy (8)		School	Education (23)
Purpose	Goal (5)		School	Teacher (7)
Purpose	God (1)		School	Food (0)

Rain	Water (14)		Sea	Water (9)
Rain	Plant (6)		Sibling	Child (32)
Rain	Sun (1)		Sibling	Parent (16)
Religion	God (18)		Sibling	Family (14)
Religion	Philosophy (16)		Sibling	Father (3)
Religion	Human (12)		Sibling	Marriage (3)
Religion	Evolution (3)		Sibling	Mother (2)
Religion	Sun (2)		Sibling	Education (0)
Sadness	Emotion (3)		Sibling	Leisure (0)
Sadness	Happiness (2)		Sorrow	Sadness (1)
Sadness	Sorrow (1)		Sport	Adolescence (0)
Sadness	Hatred (0)		Sport	Hobby (0)
Sadness	Love (0)		Sport	Oxygen (0)
Sadness	Pleasure (0)		Sun	Light (24)
School	Education (23)		Sun	Water (6)
School	Teacher (7)		Sun	Nature (4)
Sea	Water (9)		Sun	Oxygen (3)
Shoe	Clothing (1)		Sun	Birth (0)
Sibling	Parent (16)		Sun	Rain (0)
Sibling	Family (14)		Sun	Religion (0)
Sibling	Love (4)		Teacher	School (22)
Sibling	Father (3)		Teacher	Education (20)
Sibling	Marriage (3)		Teacher	Test_(assessment) (0)
Sibling	Mother (2)		Telephone	Computer (2)
Sorrow	Sadness (1)		Television	Time (6)
Sport	Television (4)		Television	Music (3)
Summer	Plant (1)		Television	Adolescence (0)
Sun	Oxygen (3)		Television	Clothing (0)
Sun	Plant (2)		Television	Computer (0)
Teacher	School (22)		Television	House (0)
Teacher	Education (20)		Television	Leisure (0)
Teacher	Learning (5)		Television	Light (0)
Teacher	Goal (0)		Television	Party (0)
Test_(assessment)	Education (5)		Television	Sport (0)
Test_(assessment)	Teacher (3)		Time	Clock (24)
Test_(assessment)	Music (1)		Time	Light (14)
Test_(assessment)	Philosophy (1)		Time	Future (12)
Time	Philosophy (26)		Time	Experience (10)
Time	Clock (24)		Time	Nature (10)
Time	Light (14)		Time	Plant (1)
Time	Future (12)		Time	Water (1)
Time	God (6)		Time	Animal (0)
Time	Religion (3)		Time	Atmosphere_of_Earth (0)
Time	Education (1)		Time	Biology (0)
Time	Television (1)		Time	Learning (0)
Tree	Forest (5)		Time	Leisure (0)
Tree	Water (3)		Time	Music (0)
Tree	Oxygen (1)		Travel	Water (0)
War	Peace (21)		Tree	Plant (14)
War	Religion (4)		Tree	Forest (5)
War	Disease (3)		War	Human (23)
War	Hatred (2)		War	Peace (21)
Water	Human (27)		War	Death (15)
Water	Sea (14)		War	Food (2)
Water	Oxygen (11)		Water	Food (26)
Water	Time (9)		Water	Sea (14)
Water	Plant (8)		Water	Oxygen (11)
Water	Rain (8)		Water	Plant (8)
Water	Sun (5)		Water	Rain (8)
Water	Organism (2)		Water	Animal (5)
Water	Travel (1)		Water	Bread (0)
Water	Biology (0)		Water	Money (0)
World	Human (5)		Water	Tree (0)
World	Experience (2)		Work	Leisure (0)

Appendix W

User interfaces of a prototype tools used by experiment group (n=49) and control group (n=24) to perform an exploration task (texts provided only in Finnish), as discussed in Subchapter 10.2.

User interface of a prototype tool used by experiment group (n=49) for exploration phase:



English translation of texts of the user interface:

Phase 1.

Your task is to traverse along a chain formed of words as logically as possible. One word at a time you must select to which direction the route of word chain should continue.

Read carefully all sentences in the list and select with mouse the sentence whose highlighted word is most naturally connected to current word (that is shown above the list). When you have proceeded 20 steps you will be automatically transferred to Phase 2.

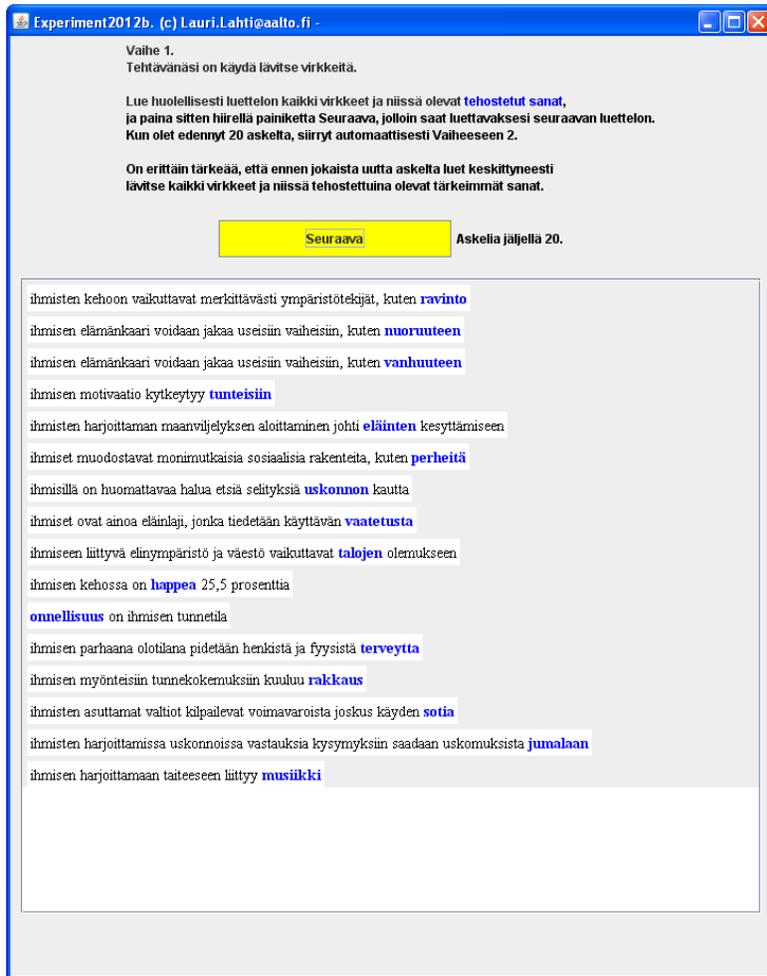
It is very important that before each new step you read attentively through all sentences and highlighted most important words in them.

Next step (20 left):

Human->?

(A list of sentences.)

User interface of a prototype tool used by control group (n=24) for exploration phase:



English translation of texts of the user interface:

Phase 1.

Your task is to traverse through sentences.

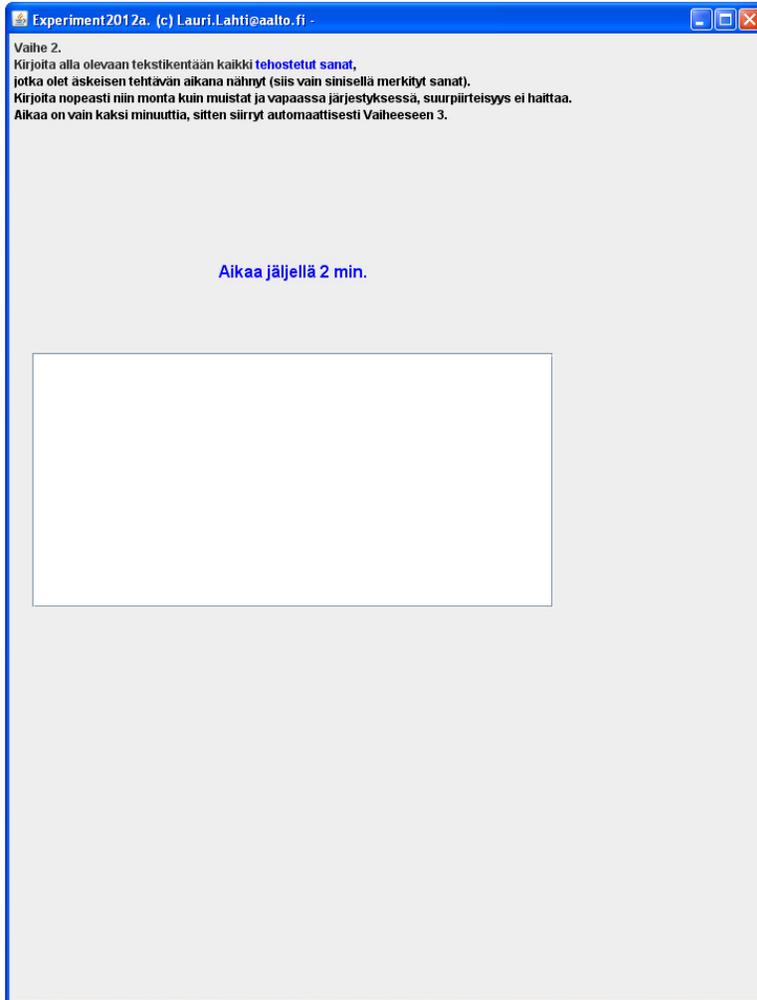
Read carefully all sentences in the list and highlighted words in them and then press button Next with mouse to get a next list to be read. When you have proceeded 20 steps you will be automatically transferred to Phase 2.

It is very important that before each new step you read attentively through all sentences and highlighted most important words in them.

Next (steps left 20).

(A list of sentences.)

User interface of a prototype tool used by both experiment group (n=49) and control group (n=24) for recalling phase:



English translation of texts of the user interface:

Phase 2.

Write into the text field below all highlighted words that you have seen during previous task (i.e. only words written in blue). Write fast as many as you can and in a free order, approximateness is not a problem. Time available only two minutes, then you will be automatically transferred to Phase 3.

Time left 2 min.

User interface of a prototype tool used by both experiment group (n=49) and control group (n=24) for phase of giving background information:

Experiment2012a. (c) Lauri.Lahti@aalto.fi

Vaihe 3.
Anna itsestäsi seuraavat taustatiedot
ja paina sitten lopuksi painiketta Tallentaminen.

Nimesi/
nimimerkki: Ikäsi: Valitse: Sukupuoles: Valitse: Kuinka hyvin
mielestäsi menestyt
koulussa? Valitse:

Jos vertaat perinteiseen kirjasta opiskeluun,
niin äsken kokeilemasi menetelmä luetun
omaksumiseen vaikuttaa... Valitse:

Opiskelijana oletko kiinnostunut
käyttämään äsken kokeilemaasi
menetelmää luetun omaksumiseen? Valitse:

Kuinka helppoa sinulle itsellesi on omaksua
uutta asiaa lukemalla? Valitse:

Kirjoita tähän kehitysehdotuksia
ja muita palautetta, jos haluat.
Mielellään myös sähköpostiosoitteesi,
jotta voisimme jatkossakin pyytää sinua
auttamaan opetusmenetelmien tutkimuksessa.

Tallentaminen
(paina kun saat työsi valmiiksi)

English translation of texts of the user interface:

Phase 3.

Give following background information about yourself and then finally press button Saving.

Your name/alias, your age (select), your gender (select).

In your opinion, how successfully do you perform at school? (select).

If you compare to traditional learning from a book, then the method you have just tried for adopting knowledge through reading appears to be..." (select).

As a student are you interested in using the method you just tried for adoption of knowledge through reading? (select).

How easy it is for you to adopt new knowledge through reading? (select).

Write here development proposals and other feedback if you want. Willingly also your email address so that we could also in the future ask you to help in the research of teaching methods.

Saving (press when you have finished your work).

In Subchapter 10.2 two learning cases are compared by asking an experiment group and a control group to perform an exploration task. Each member of the control group (n=24) had to proceed a predefined fixed series of twenty text pages, each one of them providing same kind of sentences with highlighted hyperlinked concepts as for the experiment group but without continuity between these pages and without possibility to select a hyperlink to proceed next while keeping continuity between pieces of knowledge. The predefined fixed series of twenty text pages the students had to proceed is listed here in this Appendix W. Each of twenty pages represented a concept so that all hyperlinked concepts on this page corresponded to hyperlinks going from concept represented by this page to all those hyperlinked concepts and thus all hyperlinked concepts on the same page had a shared start concept. However when proceeding to next page the concept represented by the next page was not any of those hyperlinked concepts of previous page and thus continuity between consecutive pages was minimized on purpose. This series of twenty pages was created based on exploration paths we traversed before the experiment and then reorganizing the order of pages.

Sentences of twenty pages are based on relation statements of 212 hyperlinks belonging to “hyperlink network of 55 concepts” (shown in Appendix J) that was used in exploration task of experiment group (as explained in Subchapter 10.2). In relation statement the start concept has been indicated with a notation starting with character string “A1” and ending with character string “A2” and the end concept has been indicated with a notation starting with character string “B1” and ending with character string “B2”. These notations helped to automatically highlight with different colors both start concept and end concept in relation statement when it was shown to the student during exploration experiment.

English version:

<p>Page 1: concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2; A1humanA2 life span can be split into a number of stages like B1adolescenceB2; A1humanA2 life span can be split into a number of stages like B1old ageB2; concerning A1humansA2 motivation is connected to B1emotionsB2; advent of agriculture by A1humansA2 led to domestication of B1animalsB2; A1humansA2 create complex social structures such as B1familiesB2; A1humansA2 are noted for their desire seeking explanations through B1religionB2; A1humansA2 are the only species known to B1clotheB2 themselves; concerning A1humansA2 habitat and population influence characteristics of B1housesB2; A1humanA2 body contains 25.5 percent B1oxygenB2; B1happinessB2 is a A1humanA2 emotional condition; the best condition for A1humanA2 can be considered mental and physical B1healthB2; concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2; B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources; concerning A1humanA2 religions a common source for answers to questions are beliefs in B1godB2; concerning A1humansA2 art is connected to B1musicB2;</p>
<p>Page 2: A1educationA2 encompasses teaching and B1learningB2 specific skills; A1educationA2 in secondary school occurs during B1adolescenceB2; A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are; progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate; A1educationA2 is a means to foster future development of B1humansB2; educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2; in A1educationA2 informal relationships can be established between B1teachersB2 and students; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2;</p>
<p>Page 3: concerning A1familyA2 a B1motherB2 is a female parent; concerning A1familyA2 a B1fatherB2 is a male parent; in A1familyA2 a B1siblingB2 is a child of the same parents; A1familyA2 serves to give social orientation for B1childrenB2; according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2;</p>
<p>Page 4: A1deathA2 is the end of the life of a biological B1organismB2; many factors can contribute to an organism's A1deathA2, including B1diseaseB2; A1deathA2 was once defined as the cessation of beating of B1heartB2; a loss of homeostasis of body related to A1deathA2 causes loss of B1oxygenB2; causes of A1deathA2 can be postponed by B1dietB2;</p>

<p>an autopsy is examination of a B1humanB2 corpse to determine the cause of a person's A1deathA2; B1warB2 can be considered as a situation whereby A1deathA2 assumes absolute value (taken from article War);</p>
<p>Page 5: A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees; fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2; most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide; among A1plantsA2 conifers are dominant B1treesB2; growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2; concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2; in B1natureB2 human has contributed to the extinction of many A1plantsA2; concerning A1plantsA2 in nature B1biologyB2 has a central role for life;</p>
<p>Page 6: A1childA2 as a term may define a relationship with a B1parentB2 or authority; B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2; B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2;</p>
<p>Page 7: A1animalsA2 are multicellular B1organismsB2; when talking about A1animalsA2 it is often referred to other animals than B1humansB2; A1animalsA2 generally digest food internally which separates them from B1plantsB2; A1animalsA2 benefit from plants which with carbon dioxide and B1waterB2 store the energy of sunlight; A1animalsA2 benefit from process in which the energy of sunlight helps to release B1oxygenB2; in nature B1biologyB2 has a central role for life such as A1animalsA2;</p>
<p>Page 8: A1loveA2 has many different meanings ranging to something one would die for, like B1familyB2; A1loveA2 can describe an intense feeling of affection, an B1emotionB2 or an emotional state; A1loveA2 is connected to emotions about B1happinessB2; concerning A1loveA2 B1friendshipB2 means the spirit between friends; throughout history, philosophy and B1religionB2 have done the most speculation on the phenomenon of A1loveA2; according to B1biologyB2 there are two major drives in A1loveA2: sexual attraction and attachment;</p>
<p>Page 9: components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe; existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2; the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2; liquid A1waterA2 is found in bodies of water such as B1seaB2; there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2; concerning A1waterA2 rivers and seas offer opportunity for B1travelB2; storage of A1waterA2 is important, since it is essential to B1humanB2 life; from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life;</p>
<p>Page 10: concerning A1religionA2 Isaac Newton believed that the planets revolve about the B1SunB2 and credited God with the design; A1religionA2 is related to awareness of B1GodB2 through direct personal experience; concerning A1religionA2 B1humansB2 have methods which attempt to answer fundamental questions;</p>
<p>Page 11: A1oxygenA2 in the form of O2 is produced from water e.g. by B1plantsB2 during photosynthesis; near the earth's surface ozone consisting of A1oxygenA2 is a pollutant formed from B1automobileB2 exhaust; A1oxygen therapy is used to treat B1heartB2 disorders; A1oxygen therapy is used to treat B1diseasesB2 that impair the ability to use gaseous oxygen; B1waterB2 (H2O) is the oxide of hydrogen and the most familiar A1oxygenA2 compound;</p>
<p>Page 12: part of B1biologyB2 related to A1ageingA2 is called senescence; A1old ageA2 is a stage of life preceding B1deathB2; B1childB2 is a legally important stage in personal development like also A1old ageA2; B1adolescenceB2 is a legally important stage in personal development like A1old ageA2;</p>
<p>Page 13: A1educationA2 encompasses teaching and B1learningB2 specific skills; A1educationA2 in secondary school occurs during B1adolescenceB2; A1educationA2 is a challenging task requiring an understanding of who B1childrenB2 are; progress based on A1educationA2 depends on having capacities that B1schoolingB2 can educate; A1educationA2 is a means to foster future development of B1humansB2; educational psychology related to A1educationA2 is based on psychology like medicine is based on B1biologyB2; in A1educationA2 informal relationships can be established between B1teachersB2 and students; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1educationA2 everyone has right for B1leisureB2;</p>
<p>Page 14: A1plantsA2 are a major group of life forms and include familiar B1organismsB2 such as trees; fungi are not related to photosynthetic groups of A1plantsA2 but are close relatives of B1animalsB2; most A1plantsA2 obtain their energy through photosynthesis, using B1lightB2 and carbon dioxide; among A1plantsA2 conifers are dominant B1treesB2; growth of A1plantsA2 is also determined by environmental factors, such as available B1waterB2; concerning A1plantsA2 photosynthesis changed the composition of the early Earth's atmosphere which is now 21 percent B1oxygenB2; concerning A1plantsA2 in nature B1biologyB2 has a central role for life;</p>
<p>Page 15: A1childA2 as a term may define a relationship with a B1parentB2 or authority; B1old ageB2 is a matured stage of personal development which contains also A1childhoodA2;</p>

<p>B1adolescenceB2 is a legally important stage in personal development which contains also A1childhoodA2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1brotherhoodB2; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1familyB2 life; according to the declaration of human rights that covers also A1childrenA2 everyone has right for B1leisureB2;</p>
<p>Page 16: concerning A1humansA2 body size is significantly influenced by environmental factors such as B1dietB2; A1humanA2 life span can be split into a number of stages like B1adolescenceB2; A1humanA2 life span can be split into a number of stages like B1old ageB2; concerning A1humansA2 motivation is connected to B1emotionsB2; advent of agriculture by A1humansA2 led to domestication of B1animalsB2; A1humansA2 create complex social structures such as B1familiesB2; A1humansA2 are noted for their desire seeking explanations through B1religionB2; A1humansA2 are the only species known to B1clotheB2 themselves; concerning A1humansA2 habitat and population influence characteristics of B1housesB2 ; A1humanA2 body contains 25.5 percent B1oxygenB2; B1happinessB2 is a A1humanA2 emotional condition; the best condition for A1humanA2 can be considered mental and physical B1healthB2; concerning A1humansA2 emotional experiences perceived as pleasant include B1loveB2; B1warB2 is a conflict between states of A1humansA2 involving a dispute over resources; concerning A1humansA2 art is connected to B1musicB2;</p>
<p>Page 17: A1deathA2 is the end of the life of a biological B1organismB2; many factors can contribute to an organism's A1deathA2, including B1diseaseB2; A1deathA2 was once defined as the cessation of beating of B1heartB2; a loss of homeostasis of body related to A1deathA2 causes loss of B1oxygenB2; causes of A1deathA2 can be postponed by B1dietB2; B1warB2 can be considered as a situation whereby A1deathA2 assumes absolute value (taken from article War);</p>
<p>Page 18: components of A1waterA2, hydrogen and B1oxygenB2, are among the most abundant elements in the universe; existence of A1waterA2 is vital to the existence of life on Earth like B1organismsB2; the Earth is located at such distance from the B1SunB2 allowing the three forms of A1waterA2; liquid A1waterA2 is found in bodies of water such as B1seaB2; there is a continuous exchange of A1waterA2 between ground and atmosphere through e.g. B1plantsB2; storage of A1waterA2 is important, since it is essential to B1humanB2 life; from a B1biologicalB2 standpoint, A1waterA2 has many distinct properties that are critical for the proliferation of life;</p>
<p>Page 19: concerning A1familyA2 a B1motherB2 is a female parent; concerning A1familyA2 a B1fatherB2 is a male parent; in A1familyA2 a B1siblingB2 is a child of the same parents; A1familyA2 serves to give social orientation for B1childrenB2; according to the declaration of human rights that covers also A1familyA2 everyone has right for B1leisureB2;</p>
<p>Page 20: concerning A1natureA2 one part of the Earth is more exposed to the rays of the B1SunB2; in A1natureA2 biological manifestation of life concerning B1organismsB2 is characterized by organization; in A1natureA2 properties common to organisms, such as B1plantsB2, are that they are cellular; in A1natureA2 properties common to organisms, such as B1animalsB2, are that they are cellular; in A1natureA2 B1biologyB2 has a central role for life; in A1natureA2 wilderness is generally defined as an environment that has not been directly modified by B1humanB2;</p>

Finnish version:

<p>Page 1: A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristötekijät, kuten B1ravintoB2; A1ihmisenA2 elämänkaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2; A1ihmisenA2 elämänkaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2; A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2; A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesyttämiseen; A1ihmisetA2 muodostavat monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2; A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta; A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2; A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen; A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia; B1onnellisuusB2 on A1ihmisenA2 tunnetila; A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2; A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2; A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2; A1ihmistenA2 harjoittamissa uskonnoissa vastauksia kysymyksiin saadaan uskomuksista B1jumalaanB2; A1ihmisenA2 harjoittamaan taitteeseen liittyy B1musiikkiB2;</p>
<p>Page 2: A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2; yläluokilla tarjottava A1koulutusA2 tapahtuu B1nuoruudenB2 aikana; A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat; A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa; A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittymistä; A1koulutustaA2 koskeva kasvatuspsykologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2;</p>

<p>A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 3: A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi; A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi; A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat; A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti; myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2;</p>
<p>Page 4: A1kuolemaA2 on biologisen B1eliönB2 elämän päätyminen; eliön A1kuolemaanA2 voivat vaikuttaa useat tekijät mukaan lukien B1sairaudetB2; aikoinaan A1kuolemaA2 määriteltiin B1sydämenB2 lyönnin pysähtymisenä; A1kuolemaanA2 liittyvä elimistön tasapainon menetys aiheuttaa B1hapenB2 puutetta; syitä A1kuolemaanA2 voidaan lykätä B1ravinnollaB2; ruumiinavaus on B1ihmisenB2 ruumiin tutkiminen A1kuolemanA2 syyn selvittämiseksi; B1sotaaB2 voidaan pitää tilanteena, jossa A1kuolemaA2 saa ehdottoman aseman;</p>
<p>Page 5: A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita; sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2; useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoA2 ja hiilidioksidia; A1kasvienA2 joukossa paljassimeneiset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä; A1kasvienA2 kasvu määräytyy myös ympäristötekijöistä, kuten saatavilla olevasta B1vedestäB2; A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakehää, jossa on nykyisin 21 prosenttia B1happeaB2; B1luonnossaB2 ihminen on vaikuttanut useiden A1kasvienA2 sukupuuttoon; A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle;</p>
<p>Page 6: A1lapsiA2 käsitteenä voi määritellä suhteen B1vanhempaanB2 tai auktoriteettiin; B1vanhuusB2 on kypsytynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 7: A1eläimetA2 ovat monisoluisia B1eliöitäB2; A1eläimistäA2 puhuttaessa usein viitataan muihin eläimiin kuin B1ihmisiinB2; A1eläimetA2 yleensä sulattavat ravinnon sisäisesti mikä erottaa ne B1kasveistaB2; A1eläimetA2 hyötyvät kasveista jotka hiilidioksidin ja B1vedenB2 avulla varastoivat auringonvalon energiaa ; A1eläimetA2 hyötyvät siitä että auringonvalon energian avulla vapautuu B1happeaB2; luonnossa B1biologiallaB2 on keskeinen merkitys elämälle, kuten A1eläimilleA2;</p>
<p>Page 8: A1rakkautellaA2 on eri merkityksiä ulottuen johonkin, jonka puolesta kuolla, kuten B1perheB2; A1rakkausA2 voi tarkoittaa kiihkeää kiintymystä, B1tunnettaB2 tai tunnetilaa; A1rakkauteenA2 liittyy tunteita B1onnellisuudestaB2; A1rakkauteenA2 liittyen B1ystävyyttäB2 merkitsee ystävien välillä vallitsevaa yhteishenkeä; läpi historian filosofia ja B1uskontoB2 ovat eniten spekuloineet A1rakkauttaA2 ilmiöllä; B1biologianB2 perusteella A1rakkauttaA2 on kaksi vaikutinta: seksuaalinen vetovoima ja kiintymys;</p>
<p>Page 9: A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa; A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2; maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa; nestemäistä A1vettäA2 esintyy vesistöissä, kuten B1meressäB2; A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta; A1veteenA2 liittyen joet ja meret tarjoavat tilaisuuden B1matkustamiselleB2; A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle; B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiseksi;</p>
<p>Page 10: A1uskontoonA2 liittyen Isaac Newton uskoi, että planeetat pyörivät B1auringonB2 ympäri jumalan suunnittelutyön seurauksena; A1uskontoonA2 liittyy tietoisuus B1jumalastaB2 suoran henkilökohtaisen kokemuksen kautta; A1uskontoaA2 koskien B1ihmisilläB2 on menetelmiä vastauksen saamiseksi perimmäisiin kysymyksiin;</p>
<p>Page 11: A1happiA2 muodossa O2 syntyy vedestä mm. B1kasvienB2 yhteyttämisen kautta; A1hapestaaA2 koostuva otsoni on maan pinnalla saaste, joka syntyy B1autojenB2 pakokaasuista; A1happiA2terapiaa käytetään B1sydämenB2 häiriöiden hoitoon; A1happiA2terapiaa käytetään B1sairauksienB2 hoitoon, jotka vaikeuttavat hapen käyttöä; B1vesiB2 (H2O) on vedyn oksidi ja yleisin A1happiA2yhdiste;</p>
<p>Page 12: A1vanhuuteenA2 liittyvää B1biologianB2 osa-aluetta kutsutaan seneskenssiksi; A1vanhuusA2 on B1kuolemaaB2 edeltävä elämänvaihe; B1lapsiB2 on oikeudellisesti tärkeässä yksilönkehityksen vaiheessa, jollainen on myös A1vanhuusA2; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, kuten A1vanhuusA2;</p>
<p>Page 13: A1koulutusA2 sisältää erityisten taitojen opettamista ja B1oppimistaB2; yläluokilla tarjottava A1koulutusA2 tapahtuu B1nuoruudenB2 aikana; A1koulutusA2 on vaativa tehtävä edellyttäen sen ymmärtämistä, millaisia B1lapsetB2 ovat; A1koulutukseenA2 perustuva kehitys riippuu kyvyistä joita B1koulunB2käynti voi opettaa; A1koulutusA2 on keino edistää B1ihmistenB2 tulevaisuuden kehittämistä;</p>

<p>A1koulutustaA2 koskeva kasvatuspsykologia pohjautuu psykologiaan, kuten lääketiede pohjautuu B1biologiaanB2; A1koulutuksessaA2 voi esiintyä epämuodollisia suhteita B1opettajienB2 ja opiskelijoiden välillä; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1koulutustaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 14: A1kasvitA2 ovat keskeinen ryhmä elämänmuotoja ja sisältävät tuttuja B1eliöitäB2, kuten puita; sienet eivät liity A1kasvienA2 yhteyttävään ryhmään, vaan ovat lähisukulaisia B1eläimilleB2; useat A1kasvitA2 hankkivat energiansa yhteyttämällä käyttäen B1valoaB2 ja hiilidioksidia; A1kasvienA2 joukossa paljassiemeniset ovat hallitsevia B1puitaB2 useissa eloyhteisöissä; A1kasvienA2 kasvu määräytyy myös ympäristötekijöistä, kuten saatavilla olevasta B1vedestäB2; A1kasveihinA2 liittyvä yhteyttäminen muutti varhaisen maapallon ilmakohaa, jossa on nykyisin 21 prosenttia B1happeaB2; A1kasveihinA2 liittyen luonnossa B1biologiallaB2 on keskeinen merkitys elämälle;</p>
<p>Page 15: A1lapsiA2 käsitteenä voi määritellä suhteen B1vanhempaanB2 tai auktoriteettiin; B1vanhuusB2 on kypsytynyt vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; B1nuoruusB2 on oikeudellisesti tärkeä vaihe yksilönkehityksessä, johon myös A1lapsuusA2 kuuluu; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1sisarusB2suhteisiin; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1perheB2-elämään; myös A1lapsiaA2 koskevan ihmisoikeuksien julistuksen mukaan kaikille kuuluu oikeus B1vapaa-aikaanB2;</p>
<p>Page 16: A1ihmistenA2 kehoon vaikuttavat merkittävästi ympäristötekijät, kuten B1ravintoB2; A1ihmisenA2 elämänkaari voidaan jakaa useisiin vaiheisiin, kuten B1nuoruuteenB2; A1ihmisenA2 elämänkaari voidaan jakaa useisiin vaiheisiin, kuten B1vanhuuteenB2; A1ihmisenA2 motivaatio kytkeytyy B1tunteisiinB2; A1ihmistenA2 harjoittaman maanviljelyksen aloittaminen johti B1eläintenB2 kesytämiseen; A1ihmisetA2 muodostavat monimutkaisia sosiaalisia rakenteita, kuten B1perheitäB2; A1ihmisilläA2 on huomattavaa halua etsiä selityksiä B1uskonnonB2 kautta; A1ihmisetA2 ovat ainoa eläinlaji, jonka tiedetään käyttävän B1vaatetustaB2; A1ihmiseenA2 liittyvä elinympäristö ja väestö vaikuttavat B1talojenB2 olemukseen; A1ihmisenA2 kehossa on B1happeaB2 25,5 prosenttia; B1onnellisuusB2 on A1ihmisenA2 tunnetila; A1ihmisenA2 parhaana olotilana pidetään henkistä ja fyysistä B1terveyttäB2; A1ihmisenA2 myönteisiin tunnekokemuksiin kuuluu B1rakkausB2; A1ihmistenA2 asuttamat valtiot kilpailevat voimavaroista joskus käyden B1sotiaB2; A1ihmisenA2 harjoittamaan taiteeseen liittyy B1musiikkiB2;</p>
<p>Page 17: A1kuolemaA2 on biologisen B1eliönB2 elämän päätyminen; eliön A1kuolemaanA2 voivat vaikuttaa useat tekijät mukaan lukien B1sairaudetB2; aikoinaan A1kuolemaA2 määriteltiin B1sydämenB2 lyönnin pysähtymisenä; A1kuolemaanA2 liittyvä elimistön tasapainon menetys aiheuttaa B1hapenB2 puutetta; syitä A1kuolemaanA2 voidaan lykätä B1ravinnollaB2; B1sotaaB2 voidaan pitää tilanteena, jossa A1kuolemaA2 saa ehdottoman aseman;</p>
<p>Page 18: A1vedenA2 ainesosat vety ja B1happiB2 ovat yleisimpien aineiden joukossa maailmankaikkeudessa; A1vedenA2 esiintyminen on välttämätöntä elämän olemassaololle maan päällä, kuten B1eliöilleB2; maapallo sijaitsee B1auringostaB2 etäisyydellä, joka mahdollistaa A1vedelleA2 kolme olomuotoa; nestemäistä A1vettäA2 esiintyy vesistöissä, kuten B1meressäB2; A1vesiA2 kulkee maanperän ja ilmakehän välillä mm. B1kasvienB2 kautta; A1vedenA2 varastointi on tärkeää, sillä se on olennaista B1ihmisenB2 elämälle; B1biologianB2 mukaan A1vedelläA2 on useita erityisominaisuuksia elämän edistämiseksi;</p>
<p>Page 19: A1perheeseenA2 liittyen B1äitiB2 on naispuolinen vanhempi; A1perheeseenA2 liittyen B1isäB2 on miespuolinen vanhempi; A1perheessäA2 henkilön B1sisarusB2 on lapsi, jolla on samat vanhemmat; A1perheA2 auttaa B1lastaB2 suuntautumaan sosiaalisesti; myös A1perhettäA2 koskevan ihmisoikeuksien julistuksen mukaan kaikilla on oikeus B1vapaa-aikaanB2;</p>
<p>Page 20: A1luontoonA2 liittyen osa maapallosta on enemmän altistettuna B1auringonB2 säteille; A1luonnossaA2 B1eliöitäB2 koskeva elämä ilmenee biologisesti mm. järjestäytymisenä; A1luonnossaA2 eliöille, kuten B1kasveilleB2, yleisiä ominaisuuksia on koostuminen soluista; A1luontoonA2 liittyen eliöille, kuten B1eläimilleB2, yleisiä ominaisuuksia on koostuminen soluista; A1luonnossaA2 B1biologiallaB2 on keskeinen merkitys elämälle; A1luonnossaA2 erämaana pidetään ympäristöä, jota B1ihminenB2 ei ole suoraan muokannut;</p>

Appendix X

This is a listing of background characteristics of members of experiment group (n=49) and control group (n=24) as discussed in Subchapter 10.2. For four questions the student replied by selecting a most suitable answer from a scale of five given alternatives that are listed here next.

Response alternatives for question “If you compare to traditional learning from a book, then the method you have just tried for adopting knowledge through reading appears to be...”:

Much more useful; Somewhat more useful; Equally useful; Somewhat less useful; or Much less useful.

(In Finnish: Jos vertaata perinteiseen kirjasta opiskeluun, niin äsken kokeilemasi menetelmä luetun omaksumiseen vaikuttaa... Paljon hyödyllisemmältä; Jonkin verran hyödyllisemmältä; Yhtä hyödylliseltä; Jonkin verran hyödyttömämmältä; tai Paljon hyödyttömämmältä.)

Response alternatives for question “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”:

It is very probable; It is probable; Perhaps; It is improbable; or It is very improbable.

(In Finnish: Opiskelijana oletko kiinnostunut käyttämään äsken kokeilemaasi menetelmää luetun omaksumiseen? Erittäin todennäköisesti; Todennäköisesti; Ehkä; Epätodennäköisesti; tai Erittäin epätodennäköisesti.)

Response alternatives for question “How easy it is for you to adopt new knowledge through reading?”:

Very easy; Easy; Moderate; Difficult; or Very difficult.

(In Finnish: Kuinka helppoa sinulle itsellesi on omaksua uutta asiaa lukemalla? Erittäin helppoa; Helppoa; Kohtalaista; Vaikeaa; tai Erittäin vaikeaa.)

Response alternatives for question “In your opinion, how successfully do you perform at school?”:

Excellently; Well; Satisfactorily; Fairly; or Faintly.

(In Finnish: Kuinka hyvin mielestäsi menestyt koulussa? Erinomaisesti; Hyvin; Tyydyttävästi; Välttävästi; tai Heikosti.)

Background characteristics of members of experiment group (n=49), see Subchapter 10.2 for details:

<i>Unique identifier for each member of experiment group</i>	<i>Age</i>	<i>Gender</i>	<i>Response to question: “If you compare to traditional learning from a book, then the method you have just tried for adopting knowledge through reading appears to be...”</i>	<i>Response to question: “As a student are you interested in using the method you just tried for adoption of knowledge through reading?”</i>	<i>Response to question “How easy it is for you to adopt new knowledge through reading?”</i>	<i>Response to question “In your opinion, how successfully do you perform at school?”</i>
E1	17	Female	Equally useful	Perhaps	Very easy	Well
E2	18	Female	Somewhat less useful	Perhaps	Moderate	Satisfactorily
E3	18	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E4	18	Female	Somewhat more useful	It is probable	Moderate	Satisfactorily
E5	17	Male	Somewhat less	It is probable	Moderate	Well

			useful			
E6	17	Male	Somewhat more useful	It is probable	Difficult	Satisfactorily
E7	18	Female	Somewhat more useful	It is probable	Very easy	Excellently
E8	18	Female	Somewhat more useful	Perhaps	Moderate	Well
E9	18	Female	Somewhat more useful	Perhaps	Easy	Well
E10	17	Female	Somewhat more useful	It is probable	Easy	Well
E11	17	Male	Much more useful	Perhaps	Difficult	Satisfactorily
E12	19	Male	Somewhat more useful	Perhaps	Easy	Satisfactorily
E13	17	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E14	17	Male	Somewhat more useful	It is probable	Moderate	Excellently
E15	18	Female	Somewhat more useful	It is very probable	Moderate	Satisfactorily
E16	17	Male	Somewhat less useful	It is probable	Moderate	Satisfactorily
E17	16	Male	Much more useful	It is very improbable	Very easy	Excellently
E18	17	Male	Much more useful	It is very probable	Moderate	Fairly
E19	16	Female	Equally useful	Perhaps	Moderate	Well
E20	17	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily
E21	18	Male	Somewhat more useful	Perhaps	Difficult	Satisfactorily
E22	17	Male	Much more useful	It is probable	Moderate	Satisfactorily
E23	17	Female	Equally useful	Perhaps	Easy	Well
E24	17	Female	Somewhat less useful	Perhaps	Difficult	Well
E25	16	Male	Equally useful	Perhaps	Easy	Satisfactorily
E26	16	Female	Equally useful	It is probable	Easy	Fairly
E27	17	Female	Somewhat more useful	It is probable	Easy	Satisfactorily
E28	17	Male	Equally useful	Perhaps	Easy	Excellently
E29	16	Female	Equally useful	It is probable	Easy	Satisfactorily
E30	18	Female	Equally useful	Perhaps	Moderate	Fairly
E31	17	Female	Equally useful	Perhaps	Moderate	Satisfactorily
E32	17	Female	Somewhat more useful	It is probable	Moderate	Well
E33	16	Female	Somewhat more useful	It is probable	Easy	Satisfactorily
E34	18	Female	Equally useful	Perhaps	Easy	Well
E35	17	Male	Equally useful	It is improbable	Easy	Satisfactorily
E36	19	Female	Equally useful	Perhaps	Very difficult	Well
E37	17	Female	Somewhat more useful	Perhaps	Moderate	Well
E38	17	Female	Equally useful	Perhaps	Easy	Well
E39	19	Male	Somewhat less useful	It is probable	Moderate	Satisfactorily
E40	18	Female	Somewhat more useful	It is very probable	Easy	Well
E41	17	Female	Somewhat more useful	It is probable	Difficult	Well

E42	18	Male	Somewhat more useful	It is probable	Easy	Satisfactorily
E43	17	Female	Somewhat more useful	Perhaps	Easy	Excellently
E44	17	Female	Somewhat less useful	It is improbable	Moderate	Well
E45	19	Female	Somewhat more useful	It is very probable	Moderate	Well
E46	17	Female	Much less useful	It is very improbable	Easy	Well
E47	18	Male	Equally useful	It is probable	Moderate	Satisfactorily
E48	19	Female	Equally useful	It is probable	Very difficult	Fairly
E49	19	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily

Background characteristics of members of control group (n=24), see Subchapter 10.2 for details (please note that member C10, as indicated in the listing with an asterisk (*), provided an unrealistic age of 82 years that we ignored in analysis and thus reliability of also other answers of member C10 should possibly be considered cautiously):

<i>Unique identifier for each member of control group</i>	<i>Age (N/A = not available)</i>	<i>Gender</i>	<i>Response to question: "If you compare to traditional learning from a book, then the method you have just tried for adopting knowledge through reading appears to be..."</i>	<i>Response to question: "As a student are you interested in using the method you just tried for adoption of knowledge through reading?"</i>	<i>Response to question "How easy it is for you to adopt new knowledge through reading?"</i>	<i>Response to question "In your opinion, how successfully do you perform at school?"</i>
C1	17	Female	Equally useful	Perhaps	Moderate	Satisfactorily
C2	17	Female	Much less useful	It is very improbable	Moderate	Excellently
C3	18	Female	Equally useful	Perhaps	Easy	Well
C4	17	Female	Somewhat less useful	It is improbable	Moderate	Well
C5	18	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C6	19	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C7	20	Female	Somewhat more useful	Perhaps	Easy	Satisfactorily
C8	19	Female	Equally useful	Perhaps	Moderate	Well
C9	19	Male	Somewhat more useful	It is very probable	Moderate	Satisfactorily
C10 *	N/A *	Male	Equally useful	Perhaps	Moderate	Well
C11	16	Female	Equally useful	It is probable	Easy	Well
C12	17	Male	Much more useful	It is probable	Moderate	Satisfactorily
C13	17	Male	Somewhat more useful	It is probable	Difficult	Well
C14	16	Male	Somewhat more useful	Perhaps	Moderate	Well
C15	17	Male	Somewhat less useful	Perhaps	Easy	Satisfactorily
C16	17	Female	Somewhat more useful	Perhaps	Moderate	Satisfactorily
C17	16	Male	Much more useful	It is very probable	Easy	Satisfactorily
C18	16	Female	Equally useful	It is improbable	Moderate	Well

C19	17	Male	Equally useful	Perhaps	Moderate	Satisfactorily
C20	17	Male	Somewhat less useful	It is very improbable	Very easy	Well
C21	19	Female	Somewhat more useful	It is improbable	Moderate	Satisfactorily
C22	18	Female	Equally useful	It is improbable	Easy	Satisfactorily
C23	17	Female	Somewhat less useful	Perhaps	Difficult	Satisfactorily
C24	19	Male	Somewhat less useful	It is improbable	Moderate	Satisfactorily

Appendix Y

As discussed in Subchapter 10.2 we compared two learning cases by asking an experiment group (n=49) and a control group (n=24) to perform an exploration task.

Exploration task of experiment group

Each member of the experiment group (n=49) was allowed to browse freely following their intuition in the conceptual network for twenty steps and the following listing mentions for each member of experiment group the exploration of twenty steps. This exploration task was carried in “hyperlink network of 55 concepts” (see Appendix J) starting from concept Human.

<i>Unique identifier for each member of experiment group (these identifiers correspond to those used in Appendix X)</i>	<i>Exploration path of twenty steps</i>
E1	Human->Animal->Nature->Plant->Light->Sun->Plant->Tree->Oxygen->Water->Sea->Water->Travel->Water->Biology->Organism->Biology->Nature->Sun->Oxygen->Oxygen->Disease
E2	Human->Health->Disease->Death->Disease->Death->Human->Family->Sibling->Love->Emotion->Happiness->Emotion->Love->Family->Mother->Parent->Birth->Animal->Human->Human->Love
E3	Human->Clothing->Religion->Human->House->Home->Family->Child->Adolescence->Education->School->Teacher->Learning->Experience->Learning->Education->Adolescence->Old_age->Death->Disease->Disease->Death
E4	Human->Diet_(nutrition)->Health->Biology->Human->Family->Mother->Love->Emotion->Happiness->Emotion->Experience->Emotion->Love->Friendship->Adolescence->Education->Learning->Education->Teacher->Teacher->Learning
E5	Human->Diet_(nutrition)->Health->Disease->Death->Disease->Death->War->Peace->Education->Learning->Education->Adolescence->Television->Adolescence->Education->Human->Love->Happiness->Joy->Joy->Happiness
E6	Human->Diet_(nutrition)->Health->Disease->Death->Disease->Death->War->Peace->Education->Learning->Experience->Learning->Education->School->Teacher->Learning->Teacher->School->Education->Education->Leisure
E7	Human->War->Peace->Education->Learning->Experience->Learning->Education->Adolescence->Old_age->Death->Disease->Death->Heart->Death->Oxygen->Plant->Biology->Organism->Biology->Biology->Animal
E8	Human->Health->Diet_(nutrition)->Health->Food->Human->Family->Mother->Love->Emotion->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Friendship->Adolescence->Education->Education->Learning
E9	Human->Family->Child->Family->Sibling->Love->Emotion->Experience->Emotion->Love->Friendship->Adolescence->Education->Learning->Education->Teacher->School->Education->Leisure->Work->Work->Leisure
E10	Human->Adolescence->Education->Biology->Animal->Human->Happiness->Emotion->Love->Family->Mother->Parent->Birth->Death->Heart->Death->Organism->Biology->Nature->Oxygen->Oxygen->Water
E11	Human->Family->Mother->Parent->Sibling->Love->Emotion->Experience->Emotion->Happiness->Joy->Happiness->Emotion->Love->Happiness->Love->Biology->Animal->Nature->Organism->Organism->Heart
E12	Human->Emotion->Experience->Emotion->Love->Happiness->Emotion->Joy->Happiness-

	>Joy->Happiness->Joy->Emotion->Happiness->Emotion->Happiness->Love->Friendship->Animal->Nature->Nature->Human
E13	Human->Oxygen->Plant->Biology->Human->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Family->Father->Sibling->Parent->Sibling->Love->Happiness->Love->Love->Biology
E14	Human->Diet_(nutrition)->Health->Diet_(nutrition)->Organism->Heart->Organism->Biology->Plant->Water->Oxygen->Plant->Nature->Animal->Water->Sun->Plant->Tree->Water->Travel->Travel->Water
E15	Human->Family->Sibling->Love->Happiness->Emotion->Love->Friendship->Adolescence->Education->Leisure->Television->Leisure->Work->Leisure->Family->Mother->Parent->Father->Love->Love->Emotion
E16	Human->Diet_(nutrition)->Organism->Biology->Animal->Nature->Sun->Oxygen->Water->Human->War->Disease->Death->Heart->Death->Organism->Plant->Tree->Oxygen->Disease->Disease->Oxygen
E17	Human->Diet_(nutrition)->Health->Diet_(nutrition)->Religion->God->Father->Family->Father->Mother->Parent->Mother->Love->Friendship->Animal->Organism->Plant->Nature->Oxygen->Sun->Sun->Plant
E18	Human->Religion->Sun->Oxygen->Automobile->Oxygen->Sun->Plant->Tree->Oxygen->Plant->Animal->Oxygen->Water->Travel->Water->Plant->Nature->Animal->Nature->Nature->Human
E19	Human->Emotion->Love->Emotion->Experience->Emotion->Joy->Happiness->Emotion->Happiness->Joy->Happiness->Emotion->Happiness->Joy->Emotion->Love->Friendship->Adolescence->Education->Education->School
E20	Human->Diet_(nutrition)->Death->War->Religion->God->Father->Love->Happiness->Emotion->Experience->Emotion->Joy->Happiness->Joy->Happiness->Joy->Emotion->Love->Friendship->Friendship->Adolescence
E21	Human->Health->Disease->Death->Organism->Biology->Animal->Organism->Heart->Organism->Plant->Light->Sun->Oxygen->Automobile->Oxygen->Water->Sea->Water->Oxygen->Oxygen->Sun
E22	Human->Diet_(nutrition)->Death->Oxygen->Water->Sea->Water->Sun->Plant->Light->Television->Light->Sun->Oxygen->Disease->Death->War->Peace->War->Religion->Religion->Sun
E23	Human->Emotion->Happiness->Emotion->Love->Friendship->Love->Family->Mother->Father->Parent->Child->Adolescence->Education->Learning->Experience->Learning->Education->Leisure->Work->Work->Leisure
E24	Human->Adolescence->Education->Learning->Education->Adolescence->Television->Adolescence->Child->Family->Mother->Parent->Father->Family->Father->Mother->Love->Emotion->Joy->Happiness->Happiness->Emotion
E25	Human->Adolescence->Child->Adolescence->Education->Human->Family->Mother->Father->Love->Family->Sibling->Family->Leisure->Work->Leisure->Education->Teacher->Learning->Education->Education->Learning
E26	Human->Diet_(nutrition)->Health->Disease->Death->Heart->Death->Human->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Emotion->Happiness->Emotion->Joy->Emotion->Emotion->Love
E27	Human->Diet_(nutrition)->Health->Disease->Death->War->Peace->Education->Leisure->Family->Child->Adolescence->Education->School->Education->Sibling->Love->Happiness->Joy->Happiness->Happiness->Emotion
E28	Human->Religion->Human->Emotion->Experience->Emotion->Happiness->Joy->Happiness->Emotion->Joy->Emotion->Love->Friendship->Adolescence->Child->Parent->Human->War->Peace->Peace->Education
E29	Human->Religion->Human->War->Disease->Death->Disease->Death->Organism->Biology->Nature->Plant->Oxygen->Water->Sea->Water->Sun->Plant->Tree->Oxygen->Oxygen->Heart
E30	Human->Emotion->Experience->Emotion->Love->Family->Leisure->Family->Child->Family->Mother->Family->Father->Family->Sibling->Parent->Human->Diet_(nutrition)->Organism->Plant->Plant->Nature
E31	Human->Diet_(nutrition)->Health->Biology->Health->Disease->Death->Human->Adolescence->Education->Learning->Education->School->Teacher->Learning->Experience->Learning->Teacher->School->Education->Education->Human
E32	Human->Adolescence->Old_age->Adolescence->Television->Adolescence->Child->Family->Child->Leisure->Family->Mother->Parent->Human->Health->Disease->Death->Human->Family->Leisure->Leisure->Sibling
E33	Human->Diet_(nutrition)->Health->Biology->Animal->Human->Happiness->Joy->Happiness->Emotion->Love->Friendship->Adolescence->Education->Learning->Experience->Learning-

	>Education->Leisure->Sibling->Sibling->Family
E34	Human->Emotion->Experience->Emotion->Love->Happiness->Emotion->Joy->Happiness->Joy->Happiness->Joy->Emotion->Happiness->Emotion->Happiness->Love->Biology->Organism->Biology->Biology->Human
E35	Human->Diet_(nutrition)->Organism->Heart->Organism->Biology->Health->Diet_(nutrition)->Death->Human->Health->Disease->Death->War->Peace->Education->School->Teacher->Education->Human->Human->Music
E36	Human->Happiness->Emotion->Love->Family->Leisure->Work->Leisure->Education->Adolescence->Child->Old_age->Death->War->Disease->Death->Heart->Death->Disease->Death->Death->Human
E37	Human->Adolescence->Child->Parent->Birth->Animal->Organism->Biology->Organism->Heart->Organism->Plant->Organism->Plant->Light->Sun->Oxygen->Plant->Animal->Human->Human->Clothing
E38	Human->Adolescence->Child->Family->Mother->Parent->Birth->Animal->Organism->Biology->Nature->Organism->Plant->Water->Sea->Water->Oxygen->Plant->Organism->Heart->Heart->Organism
E39	Human->Diet_(nutrition)->Organism->Biology->Nature->Human->Oxygen->Water->Biology->Organism->Plant->Water->Sea->Water->Plant->Light->Sun->Plant->Tree->Water->Water->Sun
E40	Human->House->Home->Family->Sibling->Parent->Birth->Mother->Love->Happiness->Emotion->Experience->Emotion->Joy->Happiness->Joy->Happiness->Joy->Emotion->Love->Love->Friendship
E41	Human->Adolescence->Education->Learning->Education->Teacher->School->Education->Adolescence->Child->Family->Mother->Love->Emotion->Joy->Happiness->Emotion->Love->Friendship->Adolescence->Adolescence->Old_age
E42	Human->Love->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Love->Friendship->Love->Family->Child->Parent->Human->Clothing->Television->Clothing->Religion->God->God->Father
E43	Human->Health->Disease->Death->Organism->Biology->Nature->Human->Happiness->Emotion->Experience->Emotion->Love->Biology->Human->Diet_(nutrition)->Health->Biology->Plant->Light->Light->Television
E44	Human->Diet_(nutrition)->Organism->Biology->Nature->Plant->Oxygen->Water->Sea->Water->Plant->Tree->Oxygen->Plant->Nature->Animal->Human->Health->Disease->Death->Death->Disease
E45	Human->War->Religion->God->Father->Parent->Child->Adolescence->Education->Learning->Education->Teacher->Learning->Experience->Learning->Teacher->School->Education->Biology->Organism->Organism->Heart
E46	Human->Diet_(nutrition)->Health->Biology->Nature->Organism->Biology->Human->Family->Sibling->Love->Friendship->Adolescence->Education->Learning->Experience->Learning->Education->Human->Emotion->Emotion->Experience
E47	Human->Diet_(nutrition)->Health->Disease->Death->Organism->Heart->Organism->Biology->Animal->Human->Adolescence->Child->Parent->Human->Emotion->Experience->Emotion->Joy->Happiness->Happiness->Joy
E48	Human->Health->Disease->Death->War->Peace->War->Religion->God->Father->Love->Happiness->Joy->Happiness->Emotion->Experience->Emotion->Happiness->Emotion->Love->Love->Friendship
E49	Human->Emotion->Experience->Emotion->Joy->Happiness->Emotion->Love->Biology->Nature->Sun->Plant->Organism->Biology->Organism->Plant->Nature->Animal->Nature->Oxygen->Oxygen->Heart

Following list mentions for each member of the experiment group (n=49) recalled hyperlinked concepts. Here hyperlinked concepts supplied with an asterisk (*) belong to hyperlinked concepts that have been actively selected by the student during exploration task and other hyperlinked concepts have been just shown to the student during exploration task.

Unique identifier for each member of experiment group (these identifiers correspond to those used in Appendix X)	Recalled hyperlinked concepts (hyperlinked concepts supplied with an asterisk (*) belong to hyperlinked concepts that have been actively selected by the student)
E1	Animal*; Biology; Disease*; Human; Organism*; Oxygen; Plant; Sea*; Sun; Travel*; Tree*; Water;
E2	Animal*; Death; Disease; Emotion; Family; Father; God; Happiness*; Human; Love; Mother*; Religion; Sibling*;
E3	Adolescence; Child*; Death; Disease*; Education; Family*; Home*; House*; Human*; Religion*; School*; Teacher*; Television;
E4	Biology*; Education; Family*; Father; Happiness*; Joy; Love; Mother*; Organism; School; Sibling;
E5	Adolescence; Diet_(nutrition)*; Family; Happiness; Health*; Joy*; Love*; Old_age; Peace*; War*;
E6	Disease; Education; Health*; Human; Learning; Peace*; School; Teacher; War*;
E7	Adolescence*; Animal*; Biology; Child; Death; Disease*; Heart*; Human; Old_age*; Organism*; Oxygen*; Peace*; Plant*; Tree; War*; Water;
E8	Adolescence*; Biology; Diet_(nutrition)*; Education*; Emotion; Family*; Friendship*; Happiness; Health; Human*; Joy*; Love; Mother*; School;
E9	Adolescence*; Biology; Child*; Diet_(nutrition); Education; Emotion; Experience*; Family; Father; Human; Joy; Learning*; Leisure; Love; Mother; Oxygen; School*; Sibling*; Teacher*; Television; Work*;
E10	Biology; Birth*; Death; Emotion*; Father; Happiness*; Heart*; Human*; Love*; Mother*; Nature*; Organism*; Oxygen*; Parent*; Plant; Sibling; Sun; Water*;
E11	Family*; Happiness; Joy*; Love; Mother*; Nature*; Organism*;
E12	Animal*; Biology; Emotion; Friendship*; Happiness; Joy; Love; Nature*; Oxygen; Plant; Religion;
E13	Adolescence; Biology; Emotion; Father*; Happiness; Joy*; Love; Sibling;
E14	Animal*; Biology*; Human; Organism; Travel*; Tree*; Water;
E15	Biology; Education*; Emotion; Family; Father*; Friendship*; Happiness*; Health; Joy; Leisure; Love; Mother*; Religion; Sibling*; Work*;
E16	Animal*; Biology*; Death; Disease; Human*; Organism; Oxygen; Plant*; Sun*; Tree*; Water*;
E17	Animal*; Father; Food; God*; Health*; Mother; Nature*; Plant; Religion*; Sun*;
E18	Animal; Automobile*; Biology; God; Light; Oxygen; Sun; Travel*; Tree*; Water;
E19	Adolescence*; Education*; Emotion; Family; Happiness; Human; Joy; Leisure; Love; School*; Teacher;
E20	Adolescence*; Death*; Diet_(nutrition)*; Disease; Emotion; Family; Father*; Friendship*; God*; Happiness; Human; Joy; Love; Mother; Oxygen; Peace; War*;
E21	Automobile*; Biology*; Heart*; Human; Organism; Oxygen; Plant*; Sea*; Sun; Water;
E22	Death; Disease*; God; Oxygen; Peace*; Religion*; War; Water;
E23	Birth; Education; Emotion; Experience*; Family*; Father*; Happiness*; Joy; Learning; Leisure; Love; Mother*; Sibling; Television; Work*;
E24	Emotion; Family; Father; Joy*; Love*; Mother; Parent*;
E25	Biology; Education; Father*; Leisure; Mother*; School; Sibling*; Teacher*; Television;
E26	Emotion; Happiness; Human*; Joy; Love;
E27	Adolescence*; Death*; Emotion*; Family*; Happiness; Health*; Leisure*; Love*; Peace*; School*; Sibling*; War*;
E28	Child*; Emotion; Happiness; Human; Joy; Parent*; Peace*; Religion*; War*;
E29	Biology*; Death; Disease; Emotion; God; Heart*; Love; Organism*; Oxygen; Plant; Religion*; Sun*; Tree*; War*; Water;

E30	
E31	Adolescence*; Child; Education; Family; Human; Learning; Old_age; School; Teacher;
E32	Adolescence; Death*; Disease*; Family; Health*; Human; Leisure; Old_age*;
E33	Animal*; Biology*; Education; Emotion*; Family*; Friendship*; Happiness; Human*; Joy*; Learning; Love*; Sibling*;
E34	Animal; Biology; Emotion; Family; Friendship; Happiness; Health; Heart; Human*; Joy; Love; Nature; Organism*; Plant;
E35	Biology*; Education; Food; Health; Human; Music*; Organism; Peace*; School*; Teacher*; War*;
E36	Adolescence*; Child*; Death; Diet_(nutrition); Disease; Emotion*; Family*; God; Health; Human*; Music; Old_age*; Religion; Sibling;
E37	Animal; Clothing*; Human*;
E38	Child*; Father; Heart*; Human; Mother*; Nature*; Organism; Oxygen*; Parent*; Plant; Sea*; Sibling; Sun; Tree; Water;
E39	Biology; Human*; Organism; Oxygen*; Plant; Sea*; Sun; Tree*; Water;
E40	Birth*; Emotion; Family*; Father; Friendship*; Happiness; Home*; House*; Joy; Love; Mother*; Sibling*;
E41	Adolescence; Child*; Education; Family*; Friendship*; Happiness*; Joy*; Learning*; Love; Mother*; Old_age*; School*; Teacher*;
E42	Emotion; Family*; Father*; God*; Happiness; Love;
E43	Adolescence; Animal; Biology; Diet_(nutrition)*; Emotion; Happiness*; Health; Human; Light*; Music; Old_age; Organism*; Religion; Sun; Television*;
E44	Animal*; Death*; Disease; Health*; Heart; Human*; Nature; Organism*; Oxygen; Plant; Sun; Tree*; War; Water;
E45	Biology*; Child*; Education; Father*; God*; Health; Heart*; Human; Learning; Mother; Old_age; Organism*; Parent*; Peace; Religion*; School*; Teacher; War*;
E46	Adolescence*; Biology; Child; Education; Emotion*; Family*; Father; Love*; Mother; Old_age; Organism*; School; Sibling*; Teacher; Television;
E47	Adolescence*; Animal*; Biology*; Emotion; Family; Human; Joy; Old_age; Organism; Parent*; Religion;
E48	Death*; Emotion; Family; Father*; Friendship*; God*; Joy*; Love; Mother; Nature; Religion*;
E49	Animal*; Emotion; Experience*; Happiness*; Heart*; Love*; Nature; Organism; Oxygen*; Plant; Sun*;

Exploration task of control group

During exploration task of control group originally 42 unique hyperlinked concepts were shown to each student and when considering repeated exposure of some hyperlinked concepts for control group originally on average 148 hyperlinked concepts were shown to each student meaning originally on average 3.52 occurrences of each unique hyperlinked concept. As explained in Subchapter 10.2, to make conceptual exposure of experiment group and control group more matching to enable more reliable comparison about the process of exploration tasks and suggested educational benefits gained with these exploration tasks we decided in following analysis to consider for control group only conceptual exposure concerning 34 most occurring unique hyperlinked concepts in exploration tasks of control group (when excluding eight hyperlinked concepts there were hyperlinked concepts having shared number of occurrences and here excluded hyperlinked concepts were selected in decreasing alphabetic order). Thus following analysis relies on such observation that during exploration task of control group (24 persons) 34 unique hyperlinked concepts were shown to each student and after the experiment student could recall on average 11.21 unique hyperlinked concepts (about 33.0 percent) of them. When considering repeated exposure of some hyperlinked concepts for control group on average 137 hyperlinked concepts were shown to each student meaning on average 4.03 occurrences of each unique hyperlinked concept.

When we decided in the following analysis to consider for control group only conceptual exposure concerning 34 most occurring unique hyperlinked concepts in exploration tasks of control group the original set of 42 unique hyperlinked concepts with occurrences in parenthesis were: Biology (10),

Oxygen (9), Human (8), Organism (8), Adolescence (7), Family (7), Leisure (6), Sibling (6), Animal (5), Child (5), Plant (5), Diet_(nutrition) (4), Old_age (4), Sun (4), War (4), Water (4), Disease (3), Emotion (3), Happiness (3), Heart (3), Religion (3), Clothing (2), Education (2), Father (2), God (2), Health (2), House (2), Learning (2), Light (2), Love (2), Mother (2), Music (2), Parent (2), School (2), Sea (2), Teacher (2), Tree (2), Automobile (1), Death (1), Friendship (1), Nature (1) and Travel (1). In the following analysis to consider for control group only conceptual exposure concerning 34 unique hyperlinked concepts we excluded these eight hyperlinked concepts: Sea, Teacher, Tree, Automobile, Death, Friendship, Nature and Travel (for hyperlinked concepts having shared number of occurrences (two occurrences) we excluded hyperlinked concepts in decreasing alphabetic order).

Following list mentions for each member of the control group (n=24) recalled hyperlinked concepts among all 42 unique hyperlinked concepts that were originally shown to each student. Here hyperlinked concepts supplied with an asterisk (*) belong to the original set of 42 unique hyperlinked concepts but do not belong to the final more limited set of 34 unique hyperlinked concepts, and thus hyperlinked concepts not supplied with an asterisk (*) belong to the set of 34 unique hyperlinked concepts that were used in our further analysis as discussed in Subchapter 10.2.

<i>Unique identifier for each member of control group (these identifiers corresponds to those used in Appendix X)</i>	<i>Recalled hyperlinked concepts (hyperlinked concepts supplied with an asterisk (*) belong to the original set of 42 unique hyperlinked concepts but do not belong to the final more limited set of 34 unique hyperlinked concepts, and thus hyperlinked concepts not supplied with an asterisk (*) belong to the set of 34 unique hyperlinked concepts that were used in our further analysis)</i>
C1	Adolescence; Animal; Biology; Education; Father; Leisure; Mother; Music; Old_age; Organism; Oxygen; Sibling; Sun; War; Water;
C2	Adolescence; Animal; Biology; Child; Diet_(nutrition); Father; Happiness; Health; Learning; Mother; Old_age; Organism; Oxygen; Plant; Religion; School; Sea*; Sibling; Sun; War;
C3	Adolescence; Animal; Diet_(nutrition); Emotion; Father; Friendship*; God; Leisure; Love; Mother; Old_age; Organism; Religion; Sibling; Sun; Water;
C4	Adolescence; Animal; Father; Human; Mother; Old_age; Organism; Oxygen; Parent; Plant; Sibling;
C5	Adolescence; Child; Family; Father; Leisure; Mother; Old_age; Oxygen; Religion; War; Water;
C6	Biology; Child; Education; Family; Father; Human; Learning; Mother; Nature*; Oxygen;
C7	Adolescence; Diet_(nutrition); Father; Human; Leisure; Mother; Old_age; Organism; Oxygen; Sibling;
C8	Biology; Child; Diet_(nutrition); Emotion; Human; Old_age; Organism; Religion;
C9	Adolescence; Automobile*; Biology; Child; Clothing; Diet_(nutrition); Heart; Learning; Organism; Oxygen;
C10	Automobile*; Biology; Child; Happiness; Heart; Learning; Leisure; Light; Organism; Oxygen; Tree*;
C11	Animal; Biology; Child; Death*; Education; Family; Father; Happiness; Leisure; Mother; Organism; Oxygen; Tree*;
C12	Death*; Diet_(nutrition); Family; Health; Leisure; Old_age; Religion; War; Water;
C13	Biology; Diet_(nutrition); Father; Happiness; Health; Heart; House; Human; Love; Mother; Music; Organism; Oxygen; Plant; Religion; Sea*; Sibling; Tree*;
C14	Clothing; Death*; Family; Health; Oxygen; Water;
C15	Adolescence; Animal; Death*; God; Human; Love; Old_age; Oxygen; Religion; War; Water;
C16	Biology; Emotion; Father; Leisure; Love; Mother; Organism; Sibling; Sun; War;
C17	Biology; Child; Father; Human; Mother; Oxygen; Plant; Religion; School; Sibling;
C18	Adolescence; Animal; Child; Death*; Diet_(nutrition); Emotion; Father; Leisure; Mother; Music; Old_age; Oxygen; Sibling; Water;

C19	Adolescence; Biology; Death*; Father; Learning; Leisure; Mother; Sibling;
C20	Adolescence; Animal; Biology; Child; Family; Father; Mother; Old_age; Organism; Oxygen; Religion; Sibling;
C21	Adolescence; Child; Diet_(nutrition); Emotion; Father; Health; Learning; Leisure; Light; Mother; Music; Old_age; Organism; Religion; School; Sibling; War;
C22	Animal; Death*; Diet_(nutrition); Family; Father; Leisure; Mother; Organism; Oxygen; Plant; Sibling; War; Water;
C23	Adolescence; Child; Death*; Diet_(nutrition); Education; Family; Home; Human; Nature*; Old_age; Sibling; War; Water;
C24	Adolescence; Death*; Family; Father; Health; Heart; Mother; Old_age; Organism; Oxygen; Sibling; War; Water;

Appendix Z

Based on exploration task of experiment group (n=49), as discussed in Subchapter 10.2, this listing enables comparison of 55 concepts of “hyperlink network of 55 concepts” between number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during exploration and number of unique recalled concepts in respect to hypelinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during exploration.

This listing can be contrasted with Table 10.9 that shows comparison of 55 concepts of “hyperlink network of 55 concepts” between number of times hyperlinked concepts are shown to student during exploration, number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during exploration and number of unique encountered (actively selected) hyperlinked concepts during exploration.

Number of unique recalled concepts in respect to hypelinked concepts that are actively selected by the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)			Number of unique recalled concepts in respect to hypelinked concepts that are shown (i.e. not necessarily actively selected but shown) to the student during her traversal of exploration path of 20 steps of <i>experiment group</i> (n=49)		
<i>Concept</i>	<i>Number of unique recalled selected concepts by all students</i>	<i>Average number of unique recalled selected concepts per each student</i>	<i>Concept</i>	<i>Number of unique recalled shown concepts by all students</i>	<i>Average number of unique recalled shown concepts per each student</i>
Emotion	24	0.489795918	Human	28	0.571428571
Love	24	0.489795918	Emotion	25	0.510204082
Happiness	22	0.448979592	Love	25	0.510204082
Human	18	0.367346939	Family	24	0.489795918
Organism	18	0.367346939	Biology	23	0.469387755
Biology	17	0.346938776	Happiness	22	0.448979592
Family	17	0.346938776	Joy	20	0.408163265
Joy	16	0.326530612	Organism	19	0.387755102
Education	15	0.306122449	Mother	18	0.367346939
Adolescence	14	0.285714286	Father	17	0.346938776
Animal	13	0.265306122	Adolescence	16	0.326530612
Death	13	0.265306122	Animal	15	0.306122449
Mother	13	0.265306122	Education	15	0.306122449
Oxygen	12	0.244897959	Oxygen	15	0.306122449
Disease	11	0.224489796	Sibling	14	0.285714286
Water	11	0.224489796	Death	13	0.265306122
Father	10	0.204081633	Health	13	0.265306122
Plant	10	0.204081633	Plant	13	0.265306122
War	10	0.204081633	Religion	13	0.265306122
Health	9	0.183673469	School	13	0.265306122
School	9	0.183673469	Disease	12	0.244897959
Sibling	9	0.183673469	Sun	12	0.244897959
Friendship	8	0.163265306	Water	12	0.244897959
Sun	8	0.163265306	War	11	0.224489796
Teacher	8	0.163265306	Child	10	0.204081633
Child	7	0.142857143	God	10	0.204081633
Heart	7	0.142857143	Old age	10	0.204081633
Learning	7	0.142857143	Teacher	10	0.204081633
Nature	7	0.142857143	Friendship	9	0.183673469
Peace	7	0.142857143	Heart	9	0.183673469
Religion	7	0.142857143	Nature	9	0.183673469
Tree	7	0.142857143	Peace	9	0.183673469
Leisure	6	0.12244898	Tree	9	0.183673469
Parent	6	0.12244898	Learning	7	0.142857143
God	5	0.102040816	Leisure	7	0.142857143
Diet (nutrition)	4	0.081632653	Diet (nutrition)	6	0.12244898
Old age	4	0.081632653	Parent	6	0.12244898
Sea	4	0.081632653	Television	6	0.12244898
Experience	3	0.06122449	Sea	4	0.081632653

Travel	3	0.06122449	Birth	3	0.06122449
Work	3	0.06122449	Experience	3	0.06122449
Automobile	2	0.040816327	Music	3	0.06122449
Birth	2	0.040816327	Travel	3	0.06122449
Home	2	0.040816327	Work	3	0.06122449
House	2	0.040816327	Automobile	2	0.040816327
Clothing	1	0.020408163	Food	2	0.040816327
Light	1	0.020408163	Home	2	0.040816327
Music	1	0.020408163	House	2	0.040816327
Television	1	0.020408163	Light	2	0.040816327
Cat	0	0	Clothing	1	0.020408163
Computer	0	0	Cat	0	0
Dog	0	0	Computer	0	0
Food	0	0	Dog	0	0
Pet	0	0	Pet	0	0
Telephone	0	0	Telephone	0	0

Appendix AA

As discussed in Subchapter 12.2, this listing shows unique nouns we retrieved in June-July 2013 from cumulative vocabularies of English Vocabulary Profile for six language ability levels (http://vocabulary.englishprofile.org/dictionary//word-list/uk/a1_c2/A): A1 (305 nouns), A2 (880 nouns), B1 (1761 nouns), B2 (2707 nouns), C1 (3198 nouns) and C2 (3710 nouns).

In contrast with Appendix AB, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies.

Language ability level A1 (305 nouns):

address; adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; band; bank; bar; basketball; bath; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; bottom; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; cinema; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; date; daughter; day; december; desk; dictionary; dining room; dinner; doctor; dog; doll; dollar; door; dress; drink; driver; dvd; ear; egg; email; end; evening; example; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; job; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; orange; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plane; plant; plate; player; potato; problem; quarter; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; sentence; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; subject; sugar; summer; sun; sunday; supermarket; swimming pool; table; taxi; tea; teacher; television; tennis; test; the internet; thing; thursday; ticket; time; today; toilet; tomato; tomorrow; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; waitress; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; work; world; writing; year; zoo;

Language ability level A2 (880 nouns):

accident; activity; actor; adjective; adventure; adverb; advertisement; advice; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; armchair; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; battery; bean; bear; beginner; beginning; belt; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; bookshop; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; burger; bus station; bus stop; businessman; businesswoman; calendar; call; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; centre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; chilli; church; cigarette; circle; classmate; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; colleague; college; comb; comic; company; comparative; competition; concert; contact; cook; cooker; cooking; corner; cost; countryside; cousin; cream; cricket; crisp; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; delay; dentist; department; department store; desert; dessert; diary; difference; digital camera; dinosaur; diploma; directions; disco; discount; dish; document; dr; drawer; drawing; dream; driving licence; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; fan; farmer; fashion; fast food; field; file; finger; fire; first name; fishing; flight; fog; folder; footballer; forest; fork; form; fridge; furniture; garage; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guest; guide; guidebook; guy; hall; ham; handbag; headache; headteacher; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id; id card; idea; identification; information; insect; instrument;

invitation; island; it; jam; jazz; jewellery; journey; jumper; keyboard; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; lamp; laptop; leather; left; lemon; lemonade; level; library; licence; lift; light; line; lion; list; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; maths; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; mistake; model; moment; monkey; mosque; motorbike; motorway; mountain; mouse; mp3 player; ms; mug; mushroom; nature; neck; necklace; neighbour; news; noon; north; notebook; notice; noun; nurse; occupation; offer; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; path; pc; pear; pence; penfriend; pepper; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pilot; pink; plan; plastic; platform; play; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; pound; practice; present; price; printer; prize; program; programme; project; pub; pupil; purple; purse; puzzle; queen; quiz; rabbit; race; racket; railway; raincoat; rap; rat; reason; receipt; receptionist; red; rent; rest; right; ring; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; salesperson; sauce; sausage; scarf; schoolchild; science; scissors; scooter; screen; seat; second; secretary; set; shampoo; shelf; ship; shop assistant; shorts; show; side; sightseeing; sign; silver; singer; singing; singular; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; slice; snack; snake; snowboarding; soap; sock; sofa; soft drink; software; song; sort; soul; sound; south; space; speaker; spelling; spoon; sports centre; spring; square; stadium; staff; stage; stairs; stamp; star; steak; stomach; stomach ache; storm; story; suit; suitcase; sunglasses; superlative; supper; surfing; surname; surprise; sweater; sweet; sweets; swim; swimming; swimming costume; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tie; tights; timetable; toast; toe; tonight; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; trainer; tram; trip; tune; type; tyre; umbrella; uncle; uniform; use; walk; walking; wallet; war; wash; washing machine; washing-up; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; visitor; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Language ability level B1 (1761 nouns):

ability; accent; access; accommodation; account; accountant; ache; achievement; act; action; ad; admission; advantage; advert; agency; ages; aim; air conditioning; air force; airline; alarm; alphabet; ambition; amount; angel; animation; ankle; anniversary; announcement; ant; antique; apology; appearance; application; architect; architecture; argument; arrangement; arrival; article; aspirin; assistant; athlete; athletics; atmosphere; attack; attention; attitude; attraction; audience; author; average; babysitter; backache; background; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; barman; basin; basket; battle; bay; beauty; bee; beef; behaviour; bell; benefit; bin; biography; birth; block; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; builder; bull; bunch; butcher; butterfly; button; buyer; cab; cabbage; cabin; cable; cage; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; canteen; captain; care; career; cashpoint; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; certificate; challenge; champion; championship; chance; chapter; character; charge; charity; chat show; check; check-in (counter); check-in (desk); checkout; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; composition; conclusion; condition; conference; connection; consonant; contents; contest; continent; contract; copy; corn; correction; cottage; cotton; cough; count; couple; courgette; court; cover; crash; creature; credit; crew; crime; criminal; crop; crossing; cruise; cry; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; decrease; defeat; defence; definite article; delivery; demand; departure; deposit; depth; description; design; designer; destination; detail; detective; development; diagram; diet; difficulty; direction; director; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; display; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earache; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; entry; equipment; essay; event; examiner; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extra; extreme sports; facilities; fair; fall; fare; farming; favour; favourite; fear; fee; feeling; ferry; festival; fever; fiction; fifth; fight; figure; film-maker; final; fine; finish; fire station; firefighter; firework; firm; fitness; flag; flavour; flood; flour; flu; flute; fly; folk; fool; forecast; forehead; foreigner; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; gap; generation; ghost; giraffe; go; goalkeeper; goat; goods; government; grade; grant; graphics; greeting; grill; groom; ground; guard; guess; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; hairdryer; handball; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hit; hole; honeymoon; hope; hostel; housework; hug; human; hunger; hurry; hut; ice hockey; ice skating; identity card; illness; imagination; immigration; importance; improvement; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interval; interview; invention; iron; ironing; issue; item; jail; jar; jet; jogging; joke;

journalist; judge; jug; jump; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knickers; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; league; lecture; leisure; length; lettuce; lie; lighter; lightning; limit; link; lip; liquid; literature; loan; location; lock; logo; look; lorry; lottery; love; lover; luxury; madam; mall; marriage; mate; material; maximum; meaning; membership; mess; message board; metal; method; mile; millimetre; mind; minimum; mix; modal (verb); monster; monument; mood; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; net; niece; nightclub; nightlife; nightmare; northeast; northwest; noticeboard; novel; object; occasion; ocean; officer; olive; operation; opinion; opportunity; opposite; option; orchestra; organization; oven; owner; packet; palace; pan; pants; paragraph; parcel; parking; parrot; pass; password; patient; pattern; pavement; pay; pea; peace; peach; peak; peanut; pedestrian; penguin; penny; performance; performer; period; permission; pharmacy; photocopy; phrasal verb; phrase; pie; pile; pill; pin; pineapple; pipe; pirate; planet; pleasure; plug; pocket money; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; position; possibility; postman; pot; powder; power; prayer; preparation; preposition; prescription; presentation; president; priest; primary school; prince; princess; prison; prisoner; product; profession; professor; progress; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quality; quantity; question mark; questionnaire; queue; rail; rainforest; range; reader; reception; recipe; record; recording; recycling; refreshments; refund; region; registration; relation; relationship; relative; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; reservation; resort; respect; result; return; reward; review; revision; ride; rider; robot; role; roll; romance; rose; route; routine; row; rubbish; rug; ruin; rule; run; sailor; salary; salesman; saleswoman; salmon; sand; sandal; saucepan; saucer; scene; scenery; science fiction; scientist; score; scream; sculpture; search; season; secondary school; secret; section; security; seller; sense; series; server; service; session; sex; shade; shadow; shape; shark; sheet; shock; shore; shoulder; shout; sight; signature; signpost; silence; silk; single; sir; situation; ski; skill; skin; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; southwest; souvenir; speech; speed; spice; spider; spinach; spot; spy; squash; stall; start; statue; stay; step; stick; stone; store; stranger; strawberry; stream; stress; strike; stripe; studio; study; stuff; style; success; suggestion; sum; sunrise; sunset; sunshine; support; supporter; sweatshirt; swimmer; switch; system; tablet; takeaway; talent; talk; tap; taste; tax; teaching; tear; technique; technology; temple; tense; tent; thank you; the first floor; the ground floor; the seaside; thief; thought; thriller; throat; thumb; thunder; tick; tiger; tin; tip; tissue; title; tongue; toothpaste; topic; total; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; traveller; trend; trick; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; union; unit; user; wage; valley; value; van; wardrobe; variety; warning; vase; waste; waterfall; wave; weather forecast; web; webcam; wedding; vegetarian; vehicle; weight; welcome; vet; whale; wheelchair; video clip; wildlife; windscreen; windsurfing; wing; virus; visa; visit; voice; volume; workout; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Language ability level B2 (2707 nouns):

absence; abuse; accuracy; acid; addict; addiction; addition; adjustment; admiration; adoption; advance; advertising; affair; affection; agent; agreement; agriculture; aircraft; alternative; aluminium; amazement; ambassador; amusement; analysis; analyst; ancestor; anger; anxiety; apostrophe; appeal; appreciation; approach; approval; arrest; arrow; aspect; assessment; assistance; association; astonishment; atom; attachment; attempt; aubergine; authority; availability; award; backup; badge; bakery; balance; ban; bang; banker; banking; bargain; barrier; base; basement; basis; beam; beat; belief; belongings; bench; bend; berry; bestseller; bikini; billion; bite; blade; blame; bomber; bombing; bond; bonus; booklet; bookmark; boost; bow; bra; bracket; brand; bravery; breakdown; breakthrough; breed; brick; broadband; brother-in-law; browser; bruise; budget; bulb; bullet; bumper; bun; burglar; burglary; bush; cabinet; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; cardboard; cardigan; carelessness; carnival; cast; catalogue; category; catering; cause; cell; cellar; cello; cemetery; centigrade; certainty; chaos; characteristic; charm; chart; chemical; cherry; chest; chief; chimney; choir; circumstance; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collapse; collector; collocation; colon; column; combination; comedian; comfort; command; commerce; commercial; commitment; committee; community; companion; comparison; composer; compromise; concentration; concept; concern; concrete; conductor; confession; confidence; confirmation; conflict; confusion; conjunction; consciousness; consequence; conservation; consideration; construction; consultant; consumer; container; content; context; contrast; contribution; control; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; crossroads; cruelty; cure; curiosity; cursor; curve; cycle; darkness; darling; dash; data; database; daughter-in-law; dawn; daylight; daytime; deadline; deal; dealer; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; defender; definition; delight; democracy; demonstration; denim; depression; desire; desktop; despair; destruction; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disappearance; disaster; discipline; discovery; disgrace; disguise; dishonesty; dislike; disposal; dissatisfaction; distinction; dive; division;

donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; ease; economist; economy; edition; editor; efficiency; electrician; electronics; element; embarrassment; emotion; emphasis; encouragement; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; equality; era; error; escalator; escape; estate; estimate; evidence; evil; evolution; exception; exclamation mark; exhaustion; existence; expansion; expectation; expense; explosion; export; expression; extension; extent; extract; eyebrow; eyelash; eyelid; eyesight; facility; factor; failure; faith; fame; fantasy; fat; fate; father-in-law; fault; feather; feature; feedback; female; fence; fighting; finance; fingernail; fire brigade; first language; fisherman; flame; flash; flexibility; fluency; force; fortune; fox; freedom; friendliness; frost; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; glance; global warming; god; good; gossip; graduate; graph; grave; greatness; grief; grip; grown-up; growth; guarantee; guidance; guilt; gum; guts; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; helper; highlight; hint; hip; hold; honesty; honour; hood; hook; horn; horror; host; household; human rights; humour; hunting; hyphen; icon; identity; idiom; idiot; image; immigrant; impact; imperative; impression; incident; income; increase; independence; individual; infection; inflation; influence; inhabitant; injury; input; inside; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; interior; interruption; introduction; invasion; inventor; inverted commas; investigation; investigator; investment; investor; involvement; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; kingdom; landing; landlady; landlord; lane; lap; laser; laughter; laundry; layer; laziness; lead; leaflet; leak; learner; learning; lecturer; leek; legend; leopard; liar; liberty; lid; lifestyle; lifetime; lighting; litter; liver; living; load; loaf; lobby; loss; loyalty; lung; lyrics; maintenance; majority; maker; male; management; mankind; manner; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; means; measure; measurement; medal; mention; microphone; mine; minister; minority; mint; miracle; misery; mission; mist; misunderstanding; mixture; monitor; moonlight; mother-in-law; motivation; motive; motor; motorist; movement; mud; muscle; musical; myth; nail; nation; native speaker; navy; need; needle; nerves; network; nonsense; novelist; nuisance; nursery; nut; oak; objection; objective; obligation; observation; obsession; offence; offender; opening; operator; opponent; organizer; origin; original; outline; outskirts; overtime; owl; oxygen; pace; pack; package; pancake; panic; paperwork; parachute; parade; parliament; partnership; passage; passion; patience; pause; paw; payment; pedal; penalty; pension; percentage; personality; pharmacist; phase; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; plus; point of view; poison; polar bear; policy; politeness; pond; popularity; portion; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; presence; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; process; producer; production; professional; profile; profit; programming; promotion; proof; proper; proposal; prospect; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punch; punishment; purchase; pyjamas; quarrel; query; quiet; racism; rage; rainbow; rape; rate; ray; razor; reach; reaction; reality; rebel; recession; recommendation; recovery; recreation; reduction; referee; reference; reflection; refugee; regret; regulation; rehearsal; release; relief; remains; remark; remedy; replacement; representative; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush; rush hour; sadness; safety; sale; salon; sample; satellite; satisfaction; savings; scale; scandal; scar; scent; schedule; scheme; scratch; script; seal; seed; selection; self-confidence; semicolon; semi-final; seminar; sensation; separation; servant; setting; share; shed; shell; shelter; shift; shooting; shopkeeper; shortage; shot; sickness; sigh; signal; similarity; sister-in-law; skeleton; slash; slave; slope; smoker; softness; soil; solo; son-in-law; soundtrack; source; specialist; species; spectator; spirit; splash; sponsor; spray; spread; spreadsheet; stain; standard; state; statement; statistics; steam; steel; steering wheel; stepfather; stepmother; stock; stool; stopover; storage; storey; strain; strategy; strength; string; stroke; structure; struggle; substance; substitute; suburb; subway; suffering; suffix; suicide; summary; sunlight; supplier; supply; surface; surgery; surroundings; survey; survival; survivor; suspect; suspicion; swan; sweat; swing; sword; syllable; symbol; sympathy; symptom; tabloid; tail; tale; tan; target; task; teaspoon; telecommunications; telescope; temper; temptation; tension; terminal; terms; terrace; territory; terror; terrorism; terrorist; thanks; the first person; the last minute; the second person; the third person; theft; theme; theory; therapy; thermometer; thesis; thigh; third; thirst; threat; tide; timing; tiredness; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; transfer; trap; tray; treasure; treatment; trekking; trial; triangle; tribe; trolley; trophy; trunk; trust; truth; try; tutor; understanding; unhappiness; upbringing; update; upgrade; waist; wait; ward; variation; warmth; wasp; weakness; wealth; weapon; welfare; venue; verse; version; wheat; whisky; whistle; victim; victory; widow; width; viewer; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; yell; zebra; zip;

Language ability level C1 (3198 nouns):

abortion; acceptance; accessory; accusation; acquaintance; adaptation; administration; administrator; adviser; agenda; aggression; aid; alert; allegation; allowance; ally; alteration; amateur; amendment; angle; annoyance; appetite; applause; appliance; archaeologist; archaeology; asset; assignment; assumption; assurance; attendance; auction; audition; awareness; avenue; bacteria; beak; bid; blindness; boundary;

brass; bribe; bronze; bubble; bully; bump; burden; campaign; cancellation; capability; capture; carriage; caution; cholesterol; chore; clarification; closeness; clutch; coal; collaboration; commodity; competence; completion; complex; complication; component; congestion; consent; constitution; consumption; contestant; controversy; convention; coolness; corruption; counterpart; coverage; crawl; criterion; cultivation; cutback; daycare; debut; declaration; dedication; deduction; defect; deficiency; deficit; delegate; density; deodorant; deputy; destiny; developer; diesel; digestion; directory; disapproval; discomfort; discontent; discrimination; dismissal; disorder; displacement; disrespect; disruption; dissertation; distraction; distress; distribution; disturbance; diversity; divide; dock; domain; domination; downside; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; equivalent; erosion; establishment; evaluation; exaggeration; excess; executive; exhaust; exhibit; expenses; exploration; exposure; exterior; extinction; extrovert; fabric; fairness; fascination; feast; fibre; flair; flow; fleet; flow; footstep; format; formula; foundation; friction; fright; fumes; fund; funding; fuss; gadget; gain; garment; gathering; gene; generalization; genius; geology; germ; gerund; gesture; giant; glamour; glimpse; globalization; glory; grace; greed; guideline; habitat; harassment; hardship; hate; hatred; hazard; heading; health care; historian; hospitality; housing; humanity; hunt; hygiene; iceberg; idol; illustration; implication; import; inability; inaccuracy; inclusion; inconvenience; index; indication; industrialization; infrastructure; initiative; injustice; innocence; innovation; insight; inspection; installation; instance; integration; interaction; interference; isolation; itinerary; jargon; jealousy; joint; journal; junk; junk mail; knob; labour; landmark; launch; lawn; layout; leadership; liability; liberation; limitation; listener; literacy; log; logic; loneliness; lounge; machinery; magistrate; mammal; mansion; mat; mechanism; memo; mentality; merit; migration; miner; mining; ministry; misfortune; misuse; mode; modification; move; mustard; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; norm; notion; nutrition; obesity; obstacle; occurrence; odds; opposition; optimist; organ; outcome; outlook; overdraft; overview; ownership; ozone; palm; panel; paradise; participant; pastry; peasant; peer; pensioner; perfection; perk; permit; personnel; perspective; phenomenon; pony; posture; praise; precaution; predator; pregnancy; premises; preservation; prestige; principle; print; privilege; probability; productivity; programmer; progression; projection; proportion; proposition; prosperity; prostitute; protein; provider; provision; pulse; purity; pyramid; radiation; rank; rarity; rating; ratio; readership; readiness; realization; rebellion; reconstruction; recruitment; rectangle; redevelopment; redundancy; refusal; regard; register; reign; relevance; reliability; reminder; renewal; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rip-off; rival; role model; rudeness; runway; sack; sacrifice; saint; saving; scholar; scholarship; scope; sector; self; self-esteem; selfishness; sensitivity; sequence; serial; setback; settlement; sewing; shame; shortcoming; shuttle; shyness; side effect; significance; simplicity; simulation; sketch; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; soya; spam; speciality; specification; spectrum; speculation; sphere; spine; spokesman; spokesperson; sponsorship; stability; staircase; stamina; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; striker; strip; stroll; subsidy; substitution; subtitles; successor; suitability; summit; superior; supervision; supervisor; surge; surgeon; tactic; takeover; tank; teamwork; technician; techno; telly; tendency; texture; the middle class; the upper class; the working class; therapist; thrill; tobacco; token; toll; torture; trainee; transaction; transformation; transportation; trek; triumph; tuition; turnover; twist; uncertainty; unity; unwillingness; usage; usefulness; vacancy; walker; variable; warrior; vegetation; veil; vein; well-being; vest; viewpoint; win; vine; wit; witch; workforce; workplace; workshop; worse; youngster;

Language ability level C2 (3710 nouns):

accumulation; acre; adolescent; advocate; alcoholic; alliance; allocation; ambiguity; analogy; anchor; antibiotic; anticipation; arch; army; artificial intelligence; aspiration; assault; assembly; astronomy; attribute; awe; backing; bark; barn; bet; bias; blackmail; blend; blister; blow; bribery; bundle; bureaucracy; burial; buzz; capitalism; cargo; casserole; casualty; catastrophe; chancellor; chapel; charisma; cheer; cheerfulness; chill; circuit; circulation; civilian; clarity; clash; classification; cliché; closure; clumsiness; coastline; coherence; coldness; combat; comeback; commander; complexion; complexity; compliment; conception; concession; confrontation; conscience; consensus; constraint; consultation; contempt; continuity; contraception; contraceptive; contradiction; conversion; conviction; cookie; coral; core; corpse; counselling; counsellor; coup; crack; crackdown; craving; craziness; credibility; creep; crush; crystal; custody; cutlery; decay; deception; delegation; denial; dependence; deprivation; descendant; desperation; deterrent; devastation; diagnosis; dialect; diarrhoea; dice; dignity; diplomacy; discretion; disgust; dismay; disposable income; disposition; dispute; dna; dominance; donor; doom; doorway; drain; drought; echo; elimination; embrace; empathy; endeavour; endurance; entity; essence; exile; expenditure; explosive; extremist; fake; famine; fanatic; feat; filter; fireplace; fist; flashback; flesh; fluid; focus; follower; forgery; forgiveness; formation; foul; founder; fraction; fragrance; framework; fraud; frenzy; fringe; frontier; frown; fulfilment; fury; gamble; gasp; gaze; glare; glow; glue; goodness; grain; grasp; grin; groan; grounds; gulf; hail; haul; heap; heir; heritage; hesitation; hierarchy; homelessness; horizon; hostage; hostility; humility; hypocrisy; hypothesis; ignorance; illusion; imitation; immune system; impatience; implementation; impossibility; imprisonment; impulse; incentive; inclination; indicator; indifference; individuality; inequality; infancy; infant; inferior; inferiority; influx;

inheritance; inhibition; injection; insecurity; insomnia; instinct; instruction; integrity; intellect; intellectual; intensity; intent; interpretation; intervention; intolerance; introvert; intruder; intrusion; intuition; irony; irritation; justification; kidney; knot; knuckle; lad; leap; leave; legacy; legislation; lifespan; likelihood; linen; loathing; local; loft; longevity; longing; lump; lure; margin; massacre; masterpiece; materialism; materialist; medication; mediocrity; medium; melody; memorial; mercy; merger; metaphor; millennium; mishap; misinterpretation; missile; momentum; monopoly; morale; mortality; motion; muddle; murmur; narrative; narrator; negligence; nerve; nest; normality; nostalgia; nostril; novelty; observer; odour; official; offspring; omission; openness; optimism; ordeal; orientation; ornament; orphan; outbreak; outgoings; outlet; output; outrage; overload; pact; paradigm; paradox; parallel; particle; pastime; patch; peer pressure; perception; perseverance; persistence; persuasion; pioneer; pit; plague; plea; plight; pole; portrayal; practitioner; precedent; predecessor; premium; presumption; prey; proceedings; procession; produce; propaganda; prosecution; prosecutor; protagonist; proverb; province; provocation; proximity; psychiatrist; pursuit; quest; quotation; quote; racist; radical; raid; rally; rash; read; realm; reasoning; reassurance; recognition; recollection; recruit; referendum; reform; refuge; regime; rejection; relish; remorse; repetition; representation; reproach; resemblance; resentment; residence; resignation; resilience; resistance; resolution; resolve; restraint; retailer; retention; retreat; reunion; revelation; reversal; reverse; revival; rhyme; ribbon; riches; ritual; rivalry; roar; round; ruling; saddle; sail; sanction; saying; scan; scarcity; scenario; schooling; scrap; scrutiny; self-assurance; self-awareness; self-control; self-discipline; self-reliance; self-respect; sensibility; sentiment; serenity; severity; shield; sibling; simplification; sin; sincerity; sip; siren; skull; slap; slaughter; snob; socialism; sorrow; spade; spark; specimen; spending; spite; splendour; spotlight; spouse; squad; stable; stance; standpoint; stardom; starvation; stimulus; stitch; strand; strap; stubbornness; stupidity; sufferer; superiority; supplement; surplus; suspense; sustainability; syllabus; synonym; tact; talks; taxpayer; tenant; tenderness; thinker; thread; threshold; throne; timber; toddler; tolerance; toughness; tractor; trader; trait; tranquility; transition; transmission; transplant; trash; trauma; treat; treaty; tribute; trilogy; trio; troops; turmoil; undertaking; unrest; upkeep; urge; vaccination; vaccine; validity; vandalism; vanity; warehouse; weed; velvet; venture; verdict; veteran; whim; vice; wilderness; villager; willpower; virgin; virtue; vitality; withdrawal; vocation; woodland; workaholic; worship; voter; vow; wreck; wreckage; wrinkle; xenophobia;

Appendix AB

As discussed in Subchapter 12.2, this listing shows unique nouns in high-frequency lists we retrieved in June-July 2013 from Oxford Wordlist (nouns extracted based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile) for five school levels (<http://www.oxfordwordlist.com/pages/search.asp>): Preparatory (685 nouns), Year 1 (811 nouns), Year 2 (1008 nouns), Year 3 (1412 nouns) and Year 4 (1445 nouns).

In contrast with Appendix AA, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies.

Preparatory (685 nouns):

accident; adventure; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; bath; battle; beach; bear; beat; bed; beginning; bend; bike; bird; birthday; biscuit; bit; bite; black; block; blood; blue; board; boat; bomb; bone; book; boss; bottle; bottom; bowl; box; boy; bra; branch; bread; breakfast; bride; bridge; brother; brush; bubble; builder; bump; bus; bush; butterfly; buzz; cabbage; cake; call; camera; camp; camping; can; candle; car; card; care; case; cash; castle; cat; cave; centre; cereal; certificate; chair; champion; change; channel; chart; check; cheer; cheese; cherry; chess; chicken; chief; child; chocolate; church; circus; city; class; classroom; climbing; clinic; clothes; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; corner; costume; country; couple; court; cousin; cover; crab; crash; crew; cricket; crocodile; cross; crowd; cup; cushion; cut; dad; dance; dancing; dash; day; december; delivery; dentist; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; doctor; dog; doll; dollar; dolphin; door; drawing; dream; dress; drink; drive; drop; duck; dust; dvd; eagle; ear; earth; egg; electricity; elephant; end; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; festival; fight; fighting; final; fine; finger; finish; fire; fish; fishing; flame; flat; floor; flower; flute; fly; food; foot; football; fork; fox; frame; friday; fridge; friend; frog; fruit; fun; game; garage; garden; gardening; gas; gear; ghost; giraffe; girl; glow; glove; go; goal; gold; golf; good; grandma; grass; green; grey; ground; guitar; gum; gun; guy; gymnastics; hair; hall; ham; hand; handball; hat; hate; head; headache; heart; heaven; helicopter; helmet; hero; hill; hip; history; hit; hockey; hold; hole; holiday; home; homework; honey; hood; hope; horn; horse; hospital; hotel; house; hunt; hunting; hurry; idea; ink; inside; instrument; island; it; jacket; jail; jam; jazz; jeans; jet; job; juice; jump; june; jungle; kangaroo; kick; kid; killer; killing; kind; king; kingdom; kitchen; kite; kitten; ladder; lake; land; language; left; leg; lemon; leopard; lesson; letter; lettuce; level; library; light; lighter; lightning; line; lion; list; look; lounge; love; lunch; machine; magazine; magic; mall; man; market; mat; match; mate; maths; meal; meat; medal; medicine; metal; milk; mind; mine; miss; model; monday; monkey; monster; morning; mother; motorbike; mouse; move; movie; mr; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; need; net; news; newspaper; night; noise; nose; number; ocean; office; officer; orange; orchestra; order; owner; pack; packet; paint; pair; palace; pancake; pants; paper; parade; parent; park; part; partner; party; pasta; patch; path; peace; pear; pencil; penguin; people; person; pet; phone; photo; picnic; picture; pie; piece; pig; pillow; pin; pineapple; pink; pirate; pit; pizza; place; plan; plane; planet; plant; plate; play; player; playground; poison; pole; police; policeman; pond; pony; pool; power; present; prince; princess; prize; professor; project; pub; puppy; purple; push; queen; question; rabbit; race; radio; rain; rainbow; read; reading; record; rectangle; red; reptile; rescue; restaurant; reward; rice; ride; right; ring; river; road; roar; robot; rock; rocket; roll; roof; room; rubbish; ruler; run; runner; running; sack; safety; salad; sale; sand; sandwich; saturday; sauce; sausage; saying; school; science; scooter; score; sea; second; secret; section; set; share; shark; shed; sheep; ship; shirt; shoe; shop; shopping; shot; show; shower; side; singing; sink; siren; sister; size; skate; skateboard; skateboarding; skating; skeleton; ski; skiing; sky; sleep; snake; snow; song; sort; sound; soup; space; speed; spelling; spider; sport; spot; spring; stage; stairs; stand; star; start; station; stay; stone; stop; store; storey; storm; story; stranger; street; stretch; study; stuff; sugar; summer; sun; sunday; sweet; swim; swimming; swing; sword; system; table; tail; tale; talk; tan; tap; tea; teacher; team; television; temple; tennis; tent; thanks; theatre; thing; thought; thumb; thunder; thursday; ticket; tie; tiger; timber; time; timetable; today; toe; toilet; tomato; tomorrow; tonight; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; trap; travel; treasure; tree; triangle; trick; trip; trophy; trouble; truck;

tuesday; turn; turning; tv; twist; type; umbrella; uncle; use; walk; walking; wall; war; wash; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; vest; west; vet; whale; wheel; whistle; white; video; will; village; win; wind; window; winner; winter; wish; visit; visitor; witch; voice; volcano; wolf; woman; wood; work; world; worm; wreck; writing; yard; year; yellow; zebra; zoo;

Year 1 (811 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; arrest; art; assembly; athletics; attack; baby; back; background; bacon; bag; ball; ballet; balloon; band; bang; bank; bar; barbecue; barn; base; baseball; basket; basketball; bat; bath; battle; beach; bear; beat; bed; bedroom; bee; beef; beginning; bell; bend; bike; bin; bird; birthday; biscuit; bit; black; blanket; block; blood; blow; blue; boat; body; bonus; book; boss; bottle; bottom; box; boxing; boy; brand; bread; break; breakfast; brother; brown; brush; bubble; bucket; bug; builder; building; bull; bunch; burger; bus; bush; business; butter; butterfly; button; buzz; cabin; cage; cake; call; camel; camping; can; candle; cap; car; card; cardboard; care; carpet; cash; cast; castle; cat; cave; centre; century; cereal; chain; chair; change; chaos; charge; cheese; chemist; chess; chest; chicken; child; chin; chip; chocolate; church; circle; circus; city; class; classroom; climbing; clothes; clown; club; coach; coffee; coin; cold; collar; collection; colour; commercial; competition; complex; computer; concert; contest; cook; cookie; cooking; coral; corner; cost; cottage; cotton; council; count; couple; course; court; cousin; cow; cover; crash; crawl; cream; creature; cricket; crime; criminal; crocodile; cross; crossing; cruise; cry; cucumber; cup; cupboard; cut; cycle; dad; dance; dancer; dancing; danger; darling; day; december; dentist; desert; designer; desk; devil; diamond; diet; dinner; dinosaur; directions; dirt; disco; dive; diving; dock; doctor; dog; doll; dollar; dolphin; donkey; door; dot; drawing; dream; dress; drive; driver; drop; duck; dump; dvd; earth; egg; elephant; emergency; end; ending; engine; eye; face; fact; factory; fake; fall; family; fan; farm; farmer; fashion; fat; father; favourite; field; fifth; fight; fighting; final; fine; finish; fire; fish; fishing; flag; flash; flat; flavour; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garage; garden; gardening; gate; gear; gentleman; ghost; giant; gift; giraffe; girl; glass; glasses; go; goal; goat; god; gold; golf; good; grade; grandma; grandmother; grass; green; grey; ground; group; guess; guitar; gum; gun; guy; gym; gymnastics; hair; haircut; hall; hammer; hand; handle; hat; head; headache; heart; heaven; helicopter; help; hero; hill; hit; hold; hole; holiday; home; homework; honey; honeymoon; honour; hook; hope; horse; hospital; hotel; hour; house; hug; hunting; iceberg; idea; information; inside; instructor; interview; invitation; island; it; jacket; jail; january; jar; jealousy; job; joke; joy; jump; jumper; june; jungle; kangaroo; key; keyboard; kick; kid; killer; killing; kind; king; kiss; kit; kitten; knife; lab; lady; lake; land; lane; lap; laptop; lawn; leader; leaf; leap; learning; leave; left; leg; lemon; leopard; letter; lettuce; level; library; life; light; lightning; line; lion; lip; living; look; lounge; love; lover; lunch; lunchtime; machine; magic; maker; man; march; market; marriage; mask; master; mat; match; mate; maths; matter; meal; means; meat; medal; medicine; memory; mess; message; metal; microphone; midnight; milk; mine; minute; miss; mistake; monday; money; monkey; monster; morning; mosquito; mother; motor; motorbike; mountain; mouse; moustache; mouth; move; movie; mr; mrs; ms; mud; mum; murder; murderer; mushroom; music; musical; name; narrative; nature; neck; need; neighbour; nest; net; night; noise; note; notice; november; number; ocean; opening; orange; oven; owl; owner; packet; paint; painting; pair; palace; pan; pants; paper; parcel; parent; park; part; party; pass; pastry; patch; pay; pen; pencil; penguin; people; performance; person; pet; phone; photographer; picnic; picture; piece; pig; pile; pink; pipe; pirate; pizza; place; plan; plane; planet; plate; play; player; playground; pocket; point; poison; pole; police; pond; pony; pop; port; post; postman; potato; pound; power; practice; prawn; present; prince; princess; principal; print; printer; prize; problem; proper; pub; puppy; purple; push; pyjamas; quarter; queen; quiet; rabbit; race; rain; rainbow; rainforest; rat; reach; read; reading; reason; recycling; red; register; rescue; rest; restaurant; ride; right; ring; river; road; robot; rock; rocket; roll; roof; room; rope; rose; round; row; rule; run; running; safety; sail; salad; sale; sand; sandwich; saturday; sauce; school; science; scooter; score; scream; screen; sea; season; seat; second; secret; september; session; set; sewing; shadow; shape; share; shark; shed; sheep; sheet; shell; ship; shooting; shop; shopping; shot; shout; show; shower; side; silver; singer; singing; single; sink; siren; sister; size; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; snowboarding; son; song; sound; soup; space; speed; spider; sport; spot; spread; stadium; staff; stage; stairs; stand; star; start; stay; step; stick; stop; storm; story; strawberry; street; stretch; strike; stuff; sugar; suitcase; summer; sun; sunday; surprise; sweat; swim; swimmer; swimming; swing; sword; table; tail; takeaway; talk; tank; tap; target; taste; tea; teacher; teaching; team; tennis; tent; test; thanks; thief; thing; third; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tomorrow; tonight; tool; tooth; toothbrush; top; touch; tour; towel; tower; town; toy; track; tractor; train; training; tram; travel; tray; treasure; tree; trick; trophy; trouble; truck; try; tube; tuesday; tunnel; turkey; turn; turning; tv; type; uncle; use; wait; walk; walker; walking; wall; van; war; warehouse; wash; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; version; whale; wheel; whistle; white; wife; wildlife; will; village; win; window; wing; winter; wish; visit; witch; voice; wolf; volleyball; woman; wood; wool; word; work; worker; workshop; world; worst; writing; yard; year; yellow; zoo;

Year 2 (1008 nouns):

ad; adult; adventure; aeroplane; afternoon; age; ages; air; airport; alarm; ambulance; animal; ant; apple; argument; arm; army; art; attack; august; baby; back; bacon; badge; bag; ball; balloon; banana; band; bang; barbecue; bark; barn; base; basketball; bat; bath; bathroom; battery; battle; bay; beach; beak; bear; beard; beat; bed; bedroom; bee; beer; bell; bench; bike; billion; bin; bird; birthday; biscuit; bit; bite; black; blanket; block; blood; blow; blue; board; boat; body; bomb; bone; book; boost; boot; border; boss; bottle; bottom; bow; bowl; box; boy; boyfriend; bracelet; brain; bread; break; breakfast; breath; breed; bridge; brother; brown; brush; bubble; bucket; bug; building; bull; bump; bunch; bus; bush; business; butter; butterfly; buzz; cabbage; cabinet; cage; cake; calculator; calf; call; camel; camera; camp; camping; can; cancer; candle; canteen; cap; captain; capture; car; card; care; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; cemetery; centre; chain; chair; challenge; chance; change; channel; chapter; chat; check; cheer; chef; chess; chest; chicken; chimney; chip; chocolate; choice; church; cinema; circle; city; class; classroom; cleaner; climbing; clock; clothes; cloud; clown; club; coach; code; coffee; cold; collar; collection; collector; college; colour; community; competition; computer; contact; container; contest; continent; control; cook; cookie; cooking; cooperation; coral; corner; cost; cottage; cough; count; counter; country; couple; course; court; cousin; cow; cover; crab; craft; crash; cream; creature; credit; crew; cricket; crime; crocodile; cross; cruise; cry; crystal; culture; cup; cupboard; curriculum; customer; cut; cutlery; dad; dance; dancing; darling; daughter; day; death; december; decision; deck; deer; defeat; desert; desk; dessert; devil; diamond; diary; dice; diesel; diet; dimension; dinner; dinosaur; direction; directions; disco; disease; distance; diver; diving; doctor; dog; doll; dolphin; donkey; door; download; dr; drawer; drawing; dream; dress; drink; drive; driver; drop; drought; duck; dvd; eagle; earth; edge; egg; elephant; end; enemy; engine; episode; escape; evening; event; evil; exercise; exhaust; extra; eye; face; factory; fair; fall; family; fan; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fight; fighting; final; fine; fire; fireplace; fish; fishing; fitness; flame; flash; flat; flight; flood; floor; flour; fluid; fly; food; foot; football; force; forest; form; fox; frame; freezer; friday; fridge; friend; fright; frog; frost; fruit; fuel; fun; funeral; fur; furniture; future; gain; game; gang; gap; garage; garden; gardening; gate; gear; gentleman; ghost; giant; gift; giraffe; girl; girlfriend; glass; glasses; glow; glue; go; goal; god; gold; golf; good; grade; grandfather; grandma; grandpa; grass; grave; green; grey; ground; group; guard; guess; guitar; gun; guts; guy; gymnastics; hair; haircut; ham; hand; handball; handle; harm; hat; hate; head; headache; heading; heart; heat; help; hero; hill; hip; history; hit; hobby; hockey; hold; hole; holiday; home; homework; honey; hook; hope; horn; horse; hospital; hotel; hour; house; hug; human; hunt; hunting; husband; hut; ice; idea; imagination; inch; insect; inside; instructor; interaction; island; it; jacket; jail; jam; jet; jewellery; job; joke; journey; joy; judge; jug; juice; jump; jumper; jungle; junk; kangaroo; kettle; key; kick; kid; killing; kilometre; kind; king; kiss; kitchen; kite; kitten; knife; knob; lab; laboratory; ladder; lady; lake; lamb; lamp; land; laser; laugh; lawn; lead; leader; leaf; leak; leave; left; leg; legend; lemon; lemonade; length; leopard; lesson; letter; level; library; lie; life; light; lightning; line; lion; living; loaf; local; log; look; lounge; love; lunch; lunchtime; machine; machinery; magic; mail; man; mango; march; mark; market; mask; master; match; maths; matter; may; meal; means; meat; mechanic; medal; medicine; medium; member; mention; menu; mercy; mess; message; metal; metre; microphone; midnight; milk; mind; mine; mint; miracle; mirror; miss; missile; mode; model; moment; monday; money; monkey; monster; month; morning; mother; motor; motorbike; mouse; mouth; move; movement; movie; mr; mrs; mud; mug; mum; museum; mushroom; music; musical; mystery; name; nap; neck; necklace; need; neighbour; net; news; newspaper; night; noise; nose; november; number; obstacle; ocean; october; opening; opera; opposite; orange; organ; oven; owl; owner; pack; packet; pain; paint; painting; pair; palace; palm; pan; pancake; pants; paper; parade; paragraph; parcel; parent; park; parrot; part; partner; party; pass; pasta; patch; path; paw; pay; peace; pen; pencil; penguin; people; pepper; person; pet; petrol; phone; photo; piano; picture; pie; piece; pig; pile; pillow; pink; pipe; pirate; pit; pizza; place; plan; plane; planet; planning; plant; play; player; playground; plot; point; pole; police; pond; pony; pool; pop; pork; port; pot; potato; pound; power; practice; prawn; present; presentation; president; prince; princess; principal; prize; problem; professor; promise; punch; puppy; purple; push; quarter; queen; quiet; rabbit; race; radio; rain; rainbow; rat; razor; read; reading; record; red; rescue; research; rest; restaurant; reward; rice; ride; rider; right; ring; river; road; roar; robot; rock; rocket; roll; roof; room; rope; round; roundabout; rubber; run; running; sack; salad; salt; sand; sandwich; saturday; sausage; saying; scarf; school; science; scooter; score; scratch; screen; sea; seal; search; seat; second; secret; section; seed; self; sentence; september; set; shape; share; shark; shed; sheep; sheet; shelf; shelter; ship; shoe; shooting; shop; shopkeeper; shopping; shore; shorts; shot; shoulder; show; shower; shuttle; side; sight; sign; silver; singing; sip; sir; siren; sister; skate; skeleton; skin; skirt; sky; sleep; slice; smoke; snack; snake; snow; soldier; solution; son; song; sound; soup; south; space; speed; spelling; spider; spinach; spirit; splash; spoon; spotlight; spray; spread; spring; spy; square; stable; stadium; stage; staircase; stairs; stamp; stand; star; start; state; station; stay; step; stick; stomach; stool; stop; store; storey; storm; story; straw; strawberry; street; string; student; stuff; style; subject; suit; summer; sun; sunday; surprise; survival; sweets; swim; swimming; swing; symbol; table; tail; talent; talk; tank; tap; taxi; tea; teacher; teaching; team; teaspoon; teenager; temper; tent; test; text; thanks; thermometer; thing; third; thought; thunderstorm; thursday; tie; tiger; timber; time; tin; toast; today; toe; toilet; tomorrow; tongue; tonight; tooth; toothbrush; top; topic; torch; touch; towel; tower; town; toy; track; tracksuit; tractor; train; trainer; training; tram; trap; treasure; tree; triangle; trick; trip; trophy; trouble; truck; trunk; truth; try; tuesday; tunnel; turkey; turn; turning; tv; type; tyre;

uncle; uniform; unit; university; upgrade; use; wait; walk; walking; wall; valley; war; wardrobe; warrior; wash; wasp; waste; watch; water; waterfall; wave; way; web; website; wedding; wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; victim; video; wife; will; village; win; wind; window; wing; winner; winter; wish; visit; witch; voice; volcano; wolf; woman; wood; wool; word; work; world; worry; worst; wrist; writing; yacht; yard; year; yellow; zebra; zone; zoo;

Year 3 (1412 nouns):

account; accuracy; ache; act; action; activity; actor; ad; addition; address; adult; adventure; advice; aeroplane; afternoon; age; agent; ages; air; airport; alarm; album; alcohol; allowance; alphabet; angel; angle; animal; ankle; announcement; answer; ant; apartment; apple; area; arm; army; arrest; art; artist; assistant; attack; attention; audience; august; aunt; author; autumn; award; baby; back; backing; backpack; bacon; bag; bakery; balcony; ball; ballet; balloon; banana; band; bandage; bang; bank; bar; barbecue; barber; bark; barrier; base; baseball; basement; basket; basketball; bat; bath; bathroom; battery; battle; bay; beach; beam; bean; bear; beat; beauty; bed; bedroom; bee; beef; beer; beginning; behaviour; bell; belt; bench; berry; bet; bicycle; bike; bin; bird; birthday; bit; bite; black; blackboard; blade; blanket; blend; block; blood; blow; blue; board; boat; body; bomb; bone; book; booking; boost; boss; bottle; bottom; bow; bowl; box; boxing; boy; boyfriend; brain; brake; branch; brand; bread; break; breakfast; breath; breed; bribe; brick; bride; bridge; brother; brown; brush; bubble; bucket; bug; builder; building; bulb; bull; bullet; bully; bump; bunch; burger; bus; bush; business; butter; butterfly; button; buzz; cab; cabbage; cabin; cage; cake; calculator; calendar; call; camel; camera; camp; camping; campsite; can; cancer; canteen; cap; capital; captain; capture; car; card; care; carnival; carpet; carrot; cartoon; case; cash; casserole; cast; castle; cat; cause; cave; ceiling; cell; cent; centre; cereal; chain; chair; challenge; champion; championship; chance; change; chapter; character; charge; charm; chat; check; cheer; cheese; chef; chess; chest; chicken; child; chilli; chimney; chin; chip; chocolate; choice; church; cinema; circle; circus; city; class; classic; classroom; click; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; clue; clutch; coach; coal; coat; coconut; code; coffee; coin; cola; cold; collar; collection; college; colour; column; comedy; comic; company; competition; complex; computer; concert; control; cook; cookie; cooking; core; corn; corner; cost; costume; cottage; cotton; cough; count; counter; country; couple; courage; course; court; cousin; cow; cover; crab; crack; craft; crash; cream; creature; creep; crew; cricket; crime; crocodile; cross; crowd; cruise; cry; crystal; cup; cupboard; curve; custom; customer; cut; cutlery; dad; damage; dance; dancer; dancing; danger; darkness; darling; dash; date; daughter; dawn; day; death; december; deck; deer; defeat; defence; defender; delivery; desert; design; desire; desk; dessert; detective; devil; diamond; diary; dice; diet; difference; dinner; dinosaur; directions; dirt; disaster; disc; disco; disease; disguise; dishwasher; disk; distance; dive; diver; diving; division; dock; doctor; dog; doll; dollar; dolphin; domination; donkey; doom; door; dot; dr; draft; drain; drawer; drawing; dream; dress; drink; drive; driver; drop; drum; duck; dump; dust; duty; ear; earth; earthquake; ease; east; edge; egg; electricity; element; elephant; email; empire; end; enemy; energy; engine; enthusiasm; entrance; envelope; equipment; error; escape; evening; evil; excitement; excuse; exercise; experiment; expert; explosion; explosive; expression; extra; eye; face; fact; factory; fake; fall; fame; family; fantasy; farm; farmer; fashion; fat; father; favourite; fear; feeling; female; fence; ferry; field; fifth; fight; fighting; figure; final; fine; finger; fingernail; finish; fire; fish; fishing; fist; fitness; flash; flat; flavour; flesh; flight; floor; flour; flower; flu; fly; fog; food; fool; foot; football; footballer; force; forest; form; fortune; fox; frame; friday; fridge; friend; fright; frog; fruit; fun; funeral; fur; furniture; future; game; gang; gap; garage; garden; gas; gate; gathering; gear; ghost; giant; gift; girl; glance; glass; glasses; glow; glue; go; goal; goalkeeper; god; gold; golf; good; goodness; goods; government; grade; grandfather; grandma; grandmother; grandpa; grandson; grant; grass; green; grey; grin; grip; groom; ground; group; guard; guess; guest; guide; guitar; gum; gun; guts; guy; gym; gymnastics; hail; hair; hairdresser; hall; ham; hammer; hand; handle; happiness; harmony; hat; hate; head; heading; health; heart; heat; heaven; hedge; height; helicopter; hell; helmet; help; hero; hill; history; hit; hobby; hockey; hold; hole; holiday; home; homework; honesty; honey; hood; hope; horn; horror; horse; hospital; host; hotel; hour; house; hug; human; hunt; hunting; hurry; husband; ice; idea; imagination; inch; indicator; information; ink; inside; interior; invasion; invention; investigation; invitation; iron; island; it; item; jacket; jail; jam; january; jar; jaw; jeans; jet; jewellery; job; joke; journal; journey; joy; juice; july; jump; jumper; june; jungle; junk; kangaroo; keeper; kettle; key; keyboard; kick; kid; killer; killing; kind; king; kingdom; kiss; kit; kitchen; kite; kitten; knife; knot; lab; laboratory; labour; lad; ladder; lady; lake; lamb; lamp; land; landing; lane; language; lap; laptop; laser; laugh; launch; law; lawn; layer; lead; leader; leap; learning; leave; left; leg; legend; lemon; lemonade; leopard; lesson; letter; lettuce; level; liar; library; lie; life; lifetime; lift; light; lighting; lightning; line; link; lion; lip; list; literacy; litre; liver; living; lock; log; look; lounge; love; luck; luggage; lunch; lunchtime; machine; magazine; magic; mail; man; manager; mango; mansion; map; march; mark; market; mask; master; mat; match; mate; maths; matter; may; mayor; meal; means; measure; meat; medal; medication; medicine; meeting; member; membership; mention; menu; mess; message; metal; method; microphone; midnight; milk; mind; mine; miner; minute; mirror; miss; missile; mission; mist; mistake; mix; mixture; mobile; mode; model; moment; monday; money; monkey; monster; month; mood; moonlight; morning; mother; motorbike; mountain; mouse; mouth; move; movement; movie; mr; mrs; ms; mud; mug; mum; murder; muscle; museum; music; mystery; nail; name; nap; neck; necklace; need; needle; neighbour;

nest; net; news; newspaper; night; nightmare; noise; north; nose; note; notice; number; nurse; nursery; nut; oak; object; obstacle; ocean; october; offence; office; officer; oil; onion; opening; opera; opponent; opposite; orange; oven; owl; owner; oxygen; pace; pack; packet; page; pain; paint; painting; pair; palace; pan; pancake; pants; paper; parachute; parcel; parent; park; parking; part; partner; party; pass; password; pastry; patch; path; pattern; pause; pay; pea; peace; peach; pedal; pencil; penguin; people; perfume; person; personality; pet; petrol; phone; photo; photographer; piano; picnic; picture; pie; piece; pig; pillow; pilot; pin; pineapple; pink; pirate; pit; pitch; pizza; place; plan; plane; planet; planning; plant; plastic; plate; platform; play; player; playground; pleasure; plug; plus; pocket; poem; point; pole; police; pond; pony; pool; pop; pork; port; position; post; poster; pot; potato; pound; powder; power; practice; prawn; present; president; priest; prince; princess; principal; prison; prisoner; prize; problem; professional; professor; profile; program; promise; proper; property; pub; pudding; punch; puppy; purple; push; pyjamas; pyramid; quarter; queen; quest; question; quiet; quiz; rabbit; race; radio; rail; rain; rainbow; raincoat; rally; rap; rat; rating; ray; razor; reach; read; reader; reading; reason; recipe; rectangle; red; reflection; region; relief; reply; report; rescue; research; rest; restaurant; return; revenge; rice; ride; rider; right; ring; river; road; roar; robbery; robot; rock; rocket; roll; roof; room; rope; rose; round; row; rubber; rubbish; rule; ruler; run; running; runway; rush; saddle; safety; sailing; salad; sale; salmon; salt; sand; sandwich; saturday; sauce; sausage; saying; scar; scarf; school; science; scientist; scooter; scope; score; scrap; scratch; scream; sea; seal; search; season; seat; second; secret; section; security; seed; self; sense; sentence; series; service; session; set; setting; shadow; shape; share; shark; shed; sheep; sheet; shelf; shell; shelter; shield; shift; ship; shirt; shock; shoe; shooting; shop; shopkeeper; shopping; shorts; shot; shoulder; show; shower; shuttle; side; sight; sign; signal; silence; silver; singer; singing; single; sink; sir; siren; sister; site; size; skate; skateboard; skating; skeleton; skiing; skill; skin; skirt; skull; sky; slap; sleep; slice; smell; smile; smoke; smoking; snack; snake; snow; soap; sofa; soil; soldier; solo; son; song; sort; sound; soup; source; south; space; speaker; species; speech; speed; spelling; spending; sphere; spider; spine; spirit; spoon; sport; spot; spotlight; spray; spread; spring; spy; squad; square; squash; stadium; staff; stage; stairs; stand; standard; star; start; state; station; statue; stay; steak; steam; step; stick; stomach; stone; stop; store; storey; storm; story; straw; strawberry; stream; street; stretch; strike; string; stroke; stroll; student; studio; study; stuff; subject; substance; sugar; suit; summer; sun; sunday; sunglasses; sunlight; supermarket; supporter; surface; surfing; surprise; surroundings; survivor; swan; sweat; sweet; swim; swimmer; swimming; swing; switch; sword; system; table; tail; talk; tank; tap; target; taste; taxi; tea; teacher; teaching; team; teaspoon; teenager; telescope; television; tennis; tent; term; test; text; thanks; theatre; theme; thief; thing; third; thought; thunder; thunderstorm; thursday; tick; ticket; tie; tiger; time; tin; tissue; title; toast; today; toe; toilet; tomato; tomb; tomorrow; tongue; tonight; tooth; top; topic; torch; tornado; touch; tour; tournament; towel; tower; town; toy; track; traffic; trail; train; trainer; training; transport; trap; trash; travel; tray; treasure; treat; tree; tribe; trick; trip; troops; trophy; trouble; truck; trumpet; trunk; trust; truth; try; tube; tuesday; tune; tunnel; turn; turning; tv; twin; type; tyre; uncle; underwear; uniform; unit; use; wait; walk; walking; wall; wallet; valley; van; war; wardrobe; warehouse; warning; warrior; wash; watch; water; waterfall; wave; way; weapon; weather; web; website; wedding; wednesday; week; weekend; vegetable; weight; veil; welcome; verse; version; vest; vet; whale; wheat; wheel; white; vice; video; view; wife; will; village; win; wind; window; windscreen; vine; wine; wing; winner; winter; violin; wire; wish; visit; witch; voice; volcano; wolf; woman; wood; word; work; world; worm; worry; worse; worst; vote; wrist; writer; writing; yard; year; yellow; zebra; zoo;

Year 4 (1445 nouns):

accident; accommodation; achievement; acid; act; action; activity; actor; ad; adult; advantage; adventure; advertisement; aeroplane; afternoon; age; agency; agent; ages; air; airport; alarm; alert; ambulance; amount; amusement; analysis; angel; anger; animal; ankle; answer; ant; apartment; apple; april; arch; area; arm; army; art; association; attack; attention; attraction; august; aunt; award; baby; babysitter; back; background; backpack; bacon; badge; bag; balance; balcony; ball; ballet; balloon; ban; banana; band; bandage; bang; bar; bark; barn; base; baseball; basement; basket; basketball; bat; bath; bathroom; battle; bay; beach; bear; beat; beauty; bed; bedroom; beef; beer; beginning; behaviour; bell; belongings; belt; bench; bend; bet; bicycle; bid; bike; bikini; bill; bin; bird; birth; birthday; bit; bite; black; blanket; block; blood; blow; blue; board; boat; body; bomb; bone; bonus; book; bookshelf; boost; boot; boss; bottle; bottom; bow; bowl; box; boxing; boy; boyfriend; bracelet; brain; branch; bread; break; breakfast; breath; breed; breeze; brick; bridge; brother; brown; brush; bubble; bucket; budget; bug; building; bull; bullet; bully; bump; bunch; bus; bush; butter; butterfly; button; cabin; cage; cake; call; camera; camp; camping; can; cancer; cap; capital; captain; capture; car; card; cardboard; cardigan; care; career; carpet; carrot; cartoon; case; cash; cast; castle; cat; cattle; cave; ceiling; celebration; cell; cent; centimetre; centre; century; cereal; ceremony; chain; chair; challenge; champion; championship; chance; change; channel; chaos; chapter; character; charge; charm; chat; check; cheek; cheer; cheese; chef; cherry; chest; chicken; child; chill; chilli; chimney; chin; chip; chocolate; choice; choir; church; circle; circus; city; class; classic; classmate; classroom; click; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; clown; club; clue; coach; coast; coat; code; coffee; cold; coldness; collapse; collar; colour; combination; comedy; comfort; comic; competition; computer; concert; concrete; condition; confidence; connection; contact; container; contest; control; conversation; cook; cookie; cooking; copper;

copy; corner; cost; costume; cottage; cough; country; couple; courage; course; court; cousin; cow; cover; crack; craft; crash; cream; creature; creep; crew; cricket; crime; crisis; cross; crossing; crowd; crush; cry; crystal; cup; cupboard; cure; customs; cut; dad; damage; dance; dancer; dancing; danger; darkness; darling; dash; date; daughter; day; daytime; deal; death; deck; deer; defeat; description; desert; designer; dessert; detective; devastation; devil; diamond; diary; dictionary; difference; dinner; dinosaur; directions; dirt; disaster; discipline; disco; disguise; display; distance; distraction; division; doctor; dog; doll; dollar; doom; door; doorway; drama; dream; dress; drink; drive; driver; drop; drum; duck; duty; ear; earth; earthquake; east; edge; effect; egg; elbow; election; electricity; element; elephant; emergency; encouragement; end; enemy; energy; engine; entertainment; entrance; envelope; environment; equipment; escape; estate; evening; evil; exam; examination; example; excitement; excuse; exercise; experience; experiment; exploration; explosion; explosive; expression; extra; eye; face; fact; factory; fair; fake; fall; fame; family; fan; farm; fascination; fashion; fat; father; fault; favourite; fear; february; feeling; fence; festival; fever; field; fifth; fight; fighting; figure; final; fine; finish; fire; firm; fish; fishing; flash; flavour; flight; floor; flower; flu; fly; focus; fog; food; foot; football; force; forehead; forest; form; fountain; fox; frame; freedom; freezer; friday; fridge; friend; fright; frog; fruit; fuel; fun; funeral; fur; furniture; fury; future; game; gang; garage; garden; gardening; gas; gasp; gate; gear; gender; ghost; giant; girl; girlfriend; glass; glasses; glow; glove; go; goal; goat; gold; golf; good; goods; government; grade; grandfather; grandma; grandmother; grandpa; grandson; grant; grasp; grass; grave; green; grey; grin; ground; group; guard; guess; guide; guitar; gum; gun; guts; guy; gym; gymnastics; hail; hair; haircut; hall; ham; hammer; hand; handbag; handball; handle; happiness; harm; hat; hate; head; heading; headquarters; health; heap; heart; heat; heater; heaven; heel; height; helicopter; hell; helmet; help; hero; hill; hip; history; hit; hold; holiday; home; homework; honey; hook; hope; horn; horror; horse; hospital; host; hostel; hotel; hour; house; hug; human; hunt; hunting; hurry; husband; hut; ice; idea; imagination; importance; increase; independence; information; injury; inside; insight; interview; invasion; invention; invitation; island; it; jacket; jail; jam; jar; jazz; jeans; jet; jewel; jewellery; job; journey; joy; judge; juice; july; jump; jumper; june; jungle; junk; kangaroo; kettle; key; kick; kid; killer; killing; kind; king; kingdom; kiss; kitchen; kite; kitten; knee; knife; lab; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; layer; lead; leader; leaf; league; leak; learning; leave; left; leg; legend; lemon; lemonade; leopard; lesson; letter; lettuce; level; liberty; library; lid; life; lifetime; lift; light; lighting; lightning; line; lion; liquid; list; literacy; litter; living; loaf; local; lock; log; look; lottery; lounge; love; luck; luggage; lump; lunch; lunchtime; lyrics; machine; magic; mail; maker; male; mall; man; manager; mango; mansion; manual; map; march; margin; mark; market; mask; master; mat; match; mate; material; maths; matter; may; meal; means; meat; mechanic; medal; medicine; medium; meeting; mention; mess; message; metal; metre; midnight; milk; mind; mine; miner; minute; mirror; misery; miss; mission; mist; mistake; mix; mixture; model; moment; monday; money; monkey; monopoly; monster; month; mood; morning; mosquito; mother; motor; motorbike; mountain; mouse; mouth; move; movement; movie; mr; mrs; ms; mud; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; needle; neighbour; neighbourhood; nephew; nerve; nest; net; news; newspaper; nickname; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; occasion; ocean; october; office; officer; official; oil; onion; opening; opponent; opposite; orange; order; orphan; oven; owner; pack; pain; paint; pair; palace; palm; panel; pants; paper; parachute; parade; paradise; parcel; parent; park; parrot; part; party; pass; passage; passenger; passport; pasta; patch; path; patience; pattern; pause; pay; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; pepper; performance; perfume; person; personality; pet; petrol; phone; photo; piano; picnic; picture; pie; piece; pig; pile; pill; pillow; pilot; pin; pink; pipe; pirate; pit; pitch; pizza; place; plan; plane; planet; planning; plant; plastic; plate; platform; play; player; playground; pleasure; plumber; pocket; point; poison; pole; police; policeman; pony; pool; pop; post; poster; pound; powder; power; practice; predator; present; president; pressure; price; prince; princess; principal; print; prison; prize; problem; production; professional; professor; profile; progress; project; promise; property; protection; pulse; pump; punch; punishment; puppy; purple; purpose; purse; push; puzzle; pyjamas; quarter; queen; quest; question; quiet; quiz; rabbit; race; radio; raid; railway; rain; rainbow; raincoat; rainforest; rally; rat; ray; reach; read; reading; realm; reason; recipe; rectangle; red; referee; register; release; remains; rent; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; ride; rider; right; ring; risk; river; road; roar; robbery; robot; rock; rocket; roll; roof; room; root; rope; rose; round; routine; row; rubber; rugby; rule; ruler; rumour; run; running; rush; sack; saddle; sadness; safety; sail; salad; sale; sample; sand; sandwich; saturday; sauce; saucepan; saucer; sausage; saving; saying; scar; scarf; scene; scent; scholarship; school; science; scientist; scissors; scooter; score; scream; screen; sea; search; season; seat; second; secret; section; security; seed; self; sense; september; series; servant; service; set; setting; shade; shadow; shame; shampoo; shape; share; shark; shed; sheep; sheet; shell; shelter; shift; ship; shirt; shock; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; shuttle; sickness; side; sight; sign; signal; silence; silver; simulation; singer; singing; single; sink; sir; siren; sister; site; situation; size; skate; skateboard; skateboarding; skeleton; sketch; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smell; smile; smoke; snack; snake; snow; society; soldier; son; song; sort; soul; sound; soup; south; souvenir; soya; space; spade; speaker; species; speed; spelling; spending; sphere; spider; spine; splash; spoon; sport; spot; spray; spread; spy; squad; square; stable; stadium; staff; stage; staircase; stairs;

stand; star; stardom; start; starvation; state; station; statue; status; stay; steel; step; stick; stitch; stomach; stone; stool; stop; store; storey; storm; story; stranger; strawberry; stream; street; strength; stretch; strike; string; stripe; stroke; stroll; study; stuff; style; subject; substitute; success; sugar; suit; suitcase; sum; summer; summit; sun; sunday; sunlight; sunset; sunshine; supermarket; supply; surface; surfing; surgery; surprise; surroundings; sweat; sweet; sweets; swim; swimming; swing; switch; sword; system; table; tail; tale; talk; talks; tank; tap; target; taste; taxi; tea; teacher; teaching; team; tear; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; term; terror; test; thanks; theft; theme; thief; thing; third; thought; thrill; throat; throne; thunder; thursday; tick; ticket; tide; tie; tiger; tights; timber; time; tin; tip; toast; today; toe; toilet; tomato; tomorrow; ton; tone; tongue; tonight; tooth; top; topic; torch; tornado; torture; total; touch; tour; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; trainer; training; transport; trap; travel; treasure; tree; triangle; trick; trip; trolley; trophy; trouble; truck; trust; try; tube; tuesday; tune; tunnel; turn; turning; tv; twin; type; tyre; umbrella; uncle; underwear; university; use; waist; wait; waitress; walk; walker; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warning; warrior; wash; waste; watch; water; waterfall; wave; way; weapon; weather; web; webcam; wedding; wednesday; weed; week; weekend; vegetable; vegetarian; weight; welcome; velvet; version; west; vet; whale; wheat; wheel; whistle; white; video; widow; view; wife; will; village; win; wind; window; vine; wing; winner; winter; violence; wish; visit; witch; voice; volcano; wolf; volleyball; woman; wood; wool; word; work; worker; world; worm; worry; worse; worst; vote; wreck; wreckage; writer; writing; yard; year; yell; yellow; zip; zone; zoo;

Appendix AC

As discussed in Subchapter 12.2, we identified 3710 unique nouns in vocabulary A1&A2&B1&B2&C1&C2 of English Vocabulary Profile covering cumulative vocabularies of six language ability levels ranging from A1 to C2 (as of June-July 2013). In hyperlink network of Wikipedia (as of June-July 2013) between these 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 we identified 25153 unique interconnecting hyperlinks containing 2878 unique nouns. Following listing contains all 25153 unique hyperlinks, here notation A>B denotes a hyperlink leading from concept A to concept B (corresponding to a hyperlink leading from Wikipedia article A to Wikipedia article B).

Among 2878 unique concepts the biggest subentity that enabled traversing hyperlink chains between any of concepts belonging to this subentity in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 when any hyperlink can be traversed in both actual linking direction and opposite direction contained 2850 unique concepts and there were 28 external unique concepts (shown in Appendix AD). 14 unique hyperlinks of 25153 unique interconnecting hyperlinks containing these external 28 unique concepts include: remark>comment, directions>direction, ending>end, exhaust>exhaustion, hole>opening, networking>network, northwest>southeast, programme>program, registration>register, resemblance>similarity, scene>scenery, superiority>superior, terms>term and willingness>will.

All 25153 unique hyperlinks between 3710 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 containing 2878 unique nouns:

ability>intelligence; ability>skill; abortion>contraceptive; abortion>rape; abortion>terrorism; abuse>accident; abuse>aggression; abuse>anger; abuse>anxiety; abuse>behaviour; abuse>childhood; abuse>consent; abuse>crime; abuse>criticism; abuse>denial; abuse>disability; abuse>discrimination; abuse>dislike; abuse>embarrassment; abuse>exaggeration; abuse>fear; abuse>gang; abuse>gender; abuse>harassment; abuse>harm; abuse>hatred; abuse>health; abuse>human; abuse>humility; abuse>individual; abuse>injustice; abuse>insult; abuse>jealousy; abuse>language; abuse>liberty; abuse>memory; abuse>metaphor; abuse>morale; abuse>neglect; abuse>negligence; abuse>pain; abuse>perception; abuse>persuasion; abuse>prejudice; abuse>pride; abuse>psychology; abuse>racism; abuse>rape; abuse>reputation; abuse>resentment; abuse>respect; abuse>self-esteem; abuse>shame; abuse>skill; abuse>slavery; abuse>solitude; abuse>suffering; abuse>threat; abuse>torture; abuse>vandalism; abuse>violence; accent>drawing; acceptance>anxiety; acceptance>human; acceptance>motivation; acceptance>peer pressure; acceptance>psychology; acceptance>reality; acceptance>self-esteem; acceptance>suffering; accident>injury; accident>leisure; accident>necessity; accident>safety; accident>secret; account>report; accountant>business; accountant>profession; accountant>university; ache>pain; acid>alcohol; acid>aspirin; acid>bacteria; acid>carbon dioxide; acid>cola; acid>dna; acid>fat; acid>gas; acid>liquid; acid>mammal; acid>protein; acid>solution; acid>stomach; acid>vinegar; acre>area; acre>day; acre>metre; acre>yard; act>document; act>pact; act>peace; act>war; actor>celebrity; actor>comic; actor>drama; actor>film; actor>ghost; actor>hypocrisy; actor>opera; actor>person; actor>song; actor>system; actor>television; actor>theatre; actor>tragedy; adaptation>behaviour; adaptation>climate; adaptation>crab; adaptation>deer; adaptation>evolution; adaptation>extinction; adaptation>genetics; adaptation>habitat; adaptation>immune system; adaptation>infection; adaptation>learning; addict>addiction; addiction>alcohol; addiction>anxiety; addiction>dna; addiction>gambling; addiction>genetics; addiction>motivation; addiction>reasoning; addiction>withdrawal; addition>angle; addition>apple; addition>circle; addition>computer; addition>force; addition>infant; addition>noun; addition>paper; addition>pie; addition>pressure; addition>toddler; adjective>adverb; adjective>clause; adjective>determiner; adjective>grammar; adjective>infinite; adjective>language; adjective>noun; adjective>preposition; adjective>quantity; adjective>verb; administration>management; admiration>awe; admiration>envy; adoption>abortion; adoption>court; adoption>inheritance; adoption>stereotype; adult>biology; adult>child; adult>contract; adult>employment; adult>gambling; adult>law; adult>lottery; adult>marriage; adult>person; adult>president; adult>prostitute; adult>reproduction; adult>sex; adventure>excitement; adventure>extreme sports; adventure>fear; adventure>learning; adventure>recreation; adventure>risk; adventure>tourism; adverb>adjective; adverb>clause; adverb>comparative; adverb>noun; adverb>superlative; adverb>verb; advert>advertising; advertisement>advertising; advertising>aircraft; advertising>attention; advertising>blog; advertising>brand; advertising>brochure; advertising>camera; advertising>communication; advertising>consumer; advertising>creativity; advertising>design; advertising>female; advertising>gender; advertising>household; advertising>information; advertising>logo; advertising>magazine; advertising>marketing; advertising>message; advertising>newspaper; advertising>persuasion; advertising>poster; advertising>problem; advertising>propaganda; advertising>radio; advertising>reality; advertising>rocket; advertising>tram; advertising>website; advice>advocate; advocate>court; advocate>judge; advocate>law; advocate>lawyer; advocate>profession; advocate>prosecutor; advocate>solicitor; affair>deception; affair>lie; affair>marriage; affair>sex; affection>communication; affection>emotion; affection>friendship; affection>love; affection>philosophy; affection>psychology; afternoon>evening; afternoon>midday; afternoon>midnight; afternoon>noon; afternoon>summer; age>gold; agent>robot; agent>title; aggression>adaptation; aggression>anger; aggression>animal; aggression>capitalism; aggression>evolution; aggression>fear; aggression>hostility; aggression>injustice; aggression>learning; aggression>peer pressure; aggression>poverty; aggression>property; aggression>resource; aggression>revenge; aggression>survival; aggression>trade; aggression>violence; agreement>consensus; agreement>contract; agreement>disagreement; agreement>treaty; agriculture>ant; agriculture>bean; agriculture>camel; agriculture>carbon dioxide; agriculture>cereal; agriculture>civilization; agriculture>climate; agriculture>climate change; agriculture>cotton; agriculture>donkey; agriculture>drug; agriculture>famine; agriculture>food; agriculture>fruit; agriculture>fuel; agriculture>genetics; agriculture>global warming; agriculture>grape; agriculture>harvest; agriculture>insect; agriculture>meat; agriculture>pea; agriculture>perfume; agriculture>plant; agriculture>potato; agriculture>productivity; agriculture>rice; agriculture>riot; agriculture>root; agriculture>satellite; agriculture>silk; agriculture>spice; agriculture>sustainability; agriculture>tobacco; agriculture>tractor; agriculture>vegetable; agriculture>wheat; agriculture>wine; agriculture>wool; aid>capitalism; aid>commerce; aid>country; aid>diplomacy; aid>donation; aid>government; aid>infrastructure; aid>interaction; aid>loan; aid>penguin; aid>scholar; aid>starvation; aid>transport; aid>vaccine; aid>war; air conditioning>air; air conditioning>biology; air conditioning>carbon; air conditioning>carbon dioxide; air conditioning>central heating; air conditioning>chemistry; air conditioning>climate; air conditioning>construction; air conditioning>cooking; air conditioning>frost; air conditioning>gas; air conditioning>hospital; air conditioning>ice; air conditioning>infection; air conditioning>invention; air conditioning>inventor; air conditioning>laboratory; air conditioning>laboratory; air conditioning>liquid; air conditioning>mining; air conditioning>oxygen; air conditioning>ozone; air conditioning>pressure; air conditioning>sun; air conditioning>system; air conditioning>temperature; air force>balloon; air force>bomber; air force>missile; aircraft>air; aircraft>airport; aircraft>atmosphere; aircraft>balloon; aircraft>bomber; aircraft>cargo; aircraft>flight; aircraft>helicopter; aircraft>human; aircraft>kite; aircraft>landing; aircraft>missile; aircraft>rocket; aircraft>wind; aircraft>wing; airline>aircraft; airline>airport; airline>cargo; airline>corporation; airline>fuel; airline>mail; airline>partnership; airline>passenger; airline>takeover; airline>travel; airport>accident; airport>agriculture; airport>aircraft; airport>airline; airport>bird; airport>brake; airport>concrete; airport>corporation; airport>erosion; airport>film; airport>flood; airport>fog; airport>government; airport>grass; airport>helicopter; airport>hotel; airport>ice; airport>immigration; airport>landing; airport>mountain; airport>navy; airport>politician; airport>public transport; airport>radio; airport>rain; airport>road; airport>runway; airport>snow; airport>terrorism; airport>tree; airport>weather; alarm clock>clock; alarm clock>nap; alarm clock>radio; alarm clock>sleep; alarm clock>time; album>lyrics; alcohol>acid; alcohol>alcoholic; alcohol>carbon; alcohol>carbon dioxide; alcohol>chemistry; alcohol>cholesterol; alcohol>metal; alcohol>oxygen; alcohol>perfume; alcohol>salt; alcohol>soap; allegation>complaint; allegation>fact; alliance>airline; alliance>contract; alliance>friendship; alliance>pact; alliance>treaty; allowance>supermarket; alphabet>consonant; alphabet>language; alphabet>spelling; alphabet>syllable; alphabet>turkey; alphabet>vowel; aluminium>adaptation; aluminium>bacteria; aluminium>bicycle; aluminium>carbon; aluminium>coin; aluminium>concrete; aluminium>copper; aluminium>density; aluminium>deodorant; aluminium>digestion; aluminium>door; aluminium>earth; aluminium>glass; aluminium>gold; aluminium>iron; aluminium>leather; aluminium>metal; aluminium>mirror; aluminium>ocean; aluminium>oxygen; aluminium>paint; aluminium>recycling; aluminium>rubber; aluminium>silver; aluminium>steel; aluminium>tin; aluminium>transport; aluminium>truck; aluminium>water; aluminium>wheat; aluminium>>window; aluminium>year; amateur>astronomy; amateur>baseball; amateur>basketball; amateur>boxing; amateur>hobby; amateur>professional; ambassador>diplomacy; ambassador>diplomat; ambassador>embassy; ambiguity>bank; ambiguity>creativity; ambiguity>dimension; ambiguity>gain; ambiguity>jargon; ambiguity>leadership; ambiguity>literature; ambiguity>logic; ambiguity>metre; ambiguity>music; ambiguity>paradox; ambiguity>pharmacist; ambiguity>pharmacy; ambiguity>philosopher; ambiguity>physics; ambiguity>prefix; ambiguity>rhythm; ambiguity>sadness; ambiguity>science; ambiguity>suffix; ambiguity>uncertainty; ambiguity>vocabulary; ambulance>air conditioning; ambulance>bicycle; ambulance>disaster; ambulance>electronics; ambulance>firefighter; ambulance>fuel; ambulance>helicopter; ambulance>illness; ambulance>injury; ambulance>mobile phone; ambulance>tank; ambulance>traffic light; ambulance>weapon; ambulance>vehicle; ambulance>wheelchair; amendment>constitution; amendment>contract; amendment>law; amendment>motion; amendment>parliament; amendment>referendum; amendment>verb; amusement>enjoyment; amusement>entertainment; amusement>experience; amusement>happiness; amusement>humour; amusement>laughter; amusement>pleasure; analogy>argument; analogy>atom; analogy>authority; analogy>common sense; analogy>communication; analogy>creativity; analogy>culture; analogy>emotion; analogy>evolution; analogy>explanation; analogy>fight; analogy>god; analogy>idiom; analogy>information; analogy>insect;

analogy>language; analogy>law; analogy>logic; analogy>memory; analogy>message; analogy>metaphor; analogy>perception; analogy>philosophy; analogy>politics;
analogy>precedent; analogy>probability; analogy>proverb; analogy>psychology; analogy>role; analogy>science; analogy>software; analogy>sun; analogy>truth; analogy>verb;
analogy>writing; analysis>chemistry; analysis>complexity; analysis>electronics; analysis>engineering; analysis>geology; analysis>language; analysis>literature; analysis>logic;
analysis>mixture; analysis>police; analysis>statistics; ancestor>bacteria; ancestor>dna; ancestor>evolution; ancestor>genetics; ancestor>grandparent; ancestor>parent;
anchor>chain; anchor>rope; anchor>storm; anchor>atmosphere; angel>earth; angel>evolution; angel>gender; angel>global warming; angel>god; angel>heaven;
angel>hell; angel>icon; angel>matter; angel>nature; angel>planet; angel>religion; angel>spirit; angel>star; angel>sun; angel>time; angel>aggression; angel>angel; angel>appetite;
anger>criticism; anger>devil; anger>discrimination; anger>emotion; anger>evaluation; anger>god; anger>gossip; anger>hatred; anger>hostility; anger>humility; anger>infection;
anger>intelligence; anger>negotiation; anger>pain; anger>perception; anger>punishment; anger>rage; anger>rape; anger>resentment; anger>revenge; anger>selfishness;
anger>sense; anger>songer; anger>statistics; anger>threat; anger>violence; anger>virtue; angle>ankle; angle>astronomy; angle>curve; angle>geography;
angle>kilometre; angle>star; angle>surface; angle>triangle; animal>bacteria; animal>body; animal>bone; animal>breath; animal>carbon dioxide; animal>coral; animal>digestion;
animal>evolution; animal>extinction; animal>fish; animal>gene; animal>lung; animal>mammal; animal>muscle; animal>oxygen; animal>protein; animal>reptile; animal>sunlight;
animal>trait; animation>blackboard; animation>camera; animation>computer; animation>glass; animation>illusion; animation>light; animation>software; animation>the internet;
ankle>foot; ankle>joint; ankle>pain; anniversary>birthday; anniversary>constitution; anniversary>day; anniversary>millennium; anniversary>saint; annoyance>anger;
annoyance>distract; annoyance>emotion; annoyance>frustration; annoyance>thought; answer>complaint; answer>imprisonment; answer>information; answer>lawyer;
answer>punishment; answer>question; answer>reply; ant>adaptation; ant>animal; ant>bee; ant>carbon dioxide; ant>civilization; ant>earth; ant>ecology; ant>evolution; ant>human;
ant>insect; ant>mammal; ant>muscle; ant>predator; ant>region; ant>soil; ant>trail; ant>wasp; antique>bronze; antique>pine; anxiety>authority; anxiety>digestion; anxiety>fear;
anxiety>headache; anxiety>immune system; anxiety>reality; anxiety>self-esteem; anxiety>symptom; anxiety>terror; anxiety>tradition; apartment>bathroom; apartment>bedroom;
apartment>brick; apartment>building; apartment>furniture; apartment>house; apartment>laundry; apartment>loft; apartment>parking; apartment>pet; apartment>telephone;
apartment>thrift; apartment>waste; apostrophe>advertising; apostrophe>definite article; apostrophe>dice; apostrophe>hyphen; apostrophe>noun; apostrophe>penny;
apostrophe>plural; apostrophe>punctuation; apostrophe>suffix; apostrophe>vandalism; apostrophe>vowel; appeal>law; appetite>brain; appetite>food; appetite>obesity;
applause>audience; applause>comedian; applause>concert; applause>golf; applause>jazz; applause>news; applause>opera; applause>prime minister; applause>television;
apple>ancestor; apple>carbon dioxide; apple>evil; apple>fruit; apple>leaf; apple>obesity; apple>oxygen; apple>plant; apple>proverb; apple>seed; apple>tree; apple>turkey;
apple>vinegar; application>question; april>autumn; april>month; april>october; arch>concrete; arch>erosion; arch>structure; archaeologists>archaeology; archaeology>agriculture;
archaeology>analysis; archaeology>architecture; archaeology>astronomy; archaeology>bureaucracy; archaeology>camera; archaeology>cereal; archaeology>chemistry;
archaeology>computer; archaeology>construction; archaeology>elite; archaeology>evolution; archaeology>geography; archaeology>geology; archaeology>history;
archaeology>human; archaeology>hypothesis; archaeology>iron; archaeology>kite; archaeology>library; archaeology>literacy; archaeology>map; archaeology>physics;
archaeology>plant; archaeology>religion; archaeology>science; archaeology>statistics; archaeology>tool; architect>architect; architect>artist; architect>construction;
architect>engineer; architect>engineering; architect>profession; architect>architect; architect>artist; architect>building; architect>construction; architect>craft;
architecture>design; architecture>engineer; architecture>engineering; architecture>lighting; architecture>planning; architecture>structure; architecture>sustainability;
architecture>system; area>acre; area>addition; area>analogy; area>analysis; area>circle; area>definition; area>formula; area>inch; area>length; area>metre; area>paint;
area>quantity; area>rectangle; area>shape; area>sphere; area>surface; area>triangle; area>volume; argument>analogy; argument>evidence; argument>inquiry; argument>logic;
argument>philosophy; argument>proposition; argument>reason; argument>truth; argument>validity; arm>elbow; arm>hand; arm>shoulder; arm>wrist; army>air force; army>nation;
army>soldier; army>troops; army>war; army>veteran; arrangement>cello; arrangement>guitar; arrangement>orchestra; arrangement>violin; arrest>crime; arrest>detective;
arrest>liberty; arrest>police; arrest>police station; arrest>riot; arrest>unemployment; arrow>aluminium; arrow>blood; arrow>bone; arrow>copper; arrow>feather; arrow>gram;
arrow>human; arrow>inch; arrow>plastic; arrow>quarrel; arrow>wood; art>architecture; art>beauty; art>cancer; art>coin; art>cooking; art>craft; art>creativity; art>dance; art>design;
art>dvd; art>emotion; art>farming; art>film; art>globalization; art>human; art>language; art>literature; art>medicine; art>music; art>nature; art>painting; art>peasant; art>philosophy;
art>photography; art>pollution; art>propaganda; art>sculpture; art>shape; art>theatre; artificial intelligence>computer; artificial intelligence>consciousness; artificial
intelligence>cooperation; artificial intelligence>creativity; artificial intelligence>empathy; artificial intelligence>firm; artificial intelligence>logic; artificial intelligence>mind; artificial
intelligence>paradigm; artificial intelligence>perception; artificial intelligence>probability; artificial intelligence>psychology; artificial intelligence>uncertainty; artist>actor;
artist>animation; artist>architect; artist>art; artist>astronomy; artist>ballet; artist>beauty; artist>chemistry; artist>comedy; artist>craft; artist>creativity; artist>criticism; artist>culture;
artist>dance; artist>dancing; artist>design; artist>doll; artist>drawing; artist>entertainer; artist>entertainment; artist>fiction; artist>genius; artist>history; artist>innovation; artist>lyrics;
artist>medicine; artist>music; artist>musician; artist>painting; artist>photography; artist>poetry; artist>pottery; artist>project; artist>singing; artist>skill; artist>speech;
artist>technician; artist>technology; artist>tragedy; artist>writing; aspiration>hope; aspirin>acid; aspirin>bark; aspirin>cancer; aspirin>decade; aspirin>experiment; aspirin>fever;
aspirin>gender; aspirin>heart attack; aspirin>kidney; aspirin>liver; aspirin>medication; aspirin>protein; aspirin>stomach; aspirin>stroke; aspirin>vinegar; assault>arrest;
assault>boxing; assault>police; assault>pride; assault>rape; assault>terrorism; assembly>manufacturing; assembly>meeting; assets>building; assets>cash; assets>currency;
asset>economics; asset>furniture; asset>insurance; asset>investment; asset>machinery; asset>ownership; asset>stock; asset>tool; asset>wealth; asset>website; assistance>aid;
assumption>proposition; assurance>insurance; astronomy>archaeology; astronomy>atmosphere; astronomy>atom; astronomy>calendar; astronomy>chemical;
astronomy>chemistry; astronomy>earth; astronomy>erosion; astronomy>light; astronomy>matter; astronomy>photography; astronomy>physics; astronomy>planet;
astronomy>radio; astronomy>star; astronomy>sun; astronomy>telescope; astronomy>temperature; astronomy>tornado; astronomy>trace; astronomy>wave; athletics>sport;
atmosphere>carbon dioxide; atmosphere>climate; atmosphere>dust; atmosphere>earth; atmosphere>evolution; atmosphere>force; atmosphere>gas; atmosphere>oxygen;
atmosphere>planet; atmosphere>radiation; atmosphere>space; atmosphere>sunlight; atmosphere>wind; atom>carbon; atom>carbon dioxide; atom>chemist;
atom>chemistry; atom>crystal; atom>diamond; atom>distance; atom>earth; atom>experiment; atom>force; atom>gas; atom>gold; atom>iron; atom>laser; atom>lead; atom>light;
atom>liquid; atom>matter; atom>metal; atom>minimum; atom>momentum; atom>oxygen; atom>ozone; atom>particle; atom>pressure; atom>salt; atom>spectrum; atom>star;
atom>temperature; atom>tin; atom>water; attachment>virus; attempt>arrest; attempt>crime; attempt>impossibility; attempt>judge; attempt>jury; attempt>liberty; attempt>police;
attention>distract; attention>education; attention>philosophy; attention>psychology; attention>sense; attribute>board game; attribute>database; auction>business; auction>cattle;
auction>commodity; auction>corporation; auction>debt; auction>fee; auction>marriage; auction>timber; auction>trade; auction>wool; audience>blog; audience>criticism;
audience>literature; audience>music; audience>performance; audience>person; audience>review; audience>scholar; audience>software; audience>theatre; audience>video game;
audition>actor; audition>comedy; audition>dancer; audition>jazz; audition>musician; audition>opera; audition>orchestra; audition>singer; audition>song; august>february;
august>harvest; august>january; august>march; august>month; august>tribe; august>year; aunt>nephew; aunt>niece; aunt>sister-in-law; aunt>uncle; authority>existence;
author>manufacturing; author>novel; author>person; author>writer; authority>court; authority>crowd; authority>dominance; authority>government; authority>persuasion;
authority>prayer; authority>revolution; autumn>apple; autumn>baseball; autumn>cherry; autumn>harvest; autumn>night; autumn>oak; autumn>season; autumn>summer;
autumn>winter; availability>system; award>badge; award>championship; award>medal; award>prize; award>trophy; awareness>attention; awareness>brain;
awareness>concept; awareness>consciousness; awareness>experience; awareness>idea; awareness>mind; awareness>pattern; awareness>perception; awareness>self-
awareness; awareness>understanding; awe>anger; awe>curiosity; awe>dinosaur; awe>embarrassment; awe>emotion; awe>enjoyment; awe>fear; awe>happiness; awe>love;
awe>pride; awe>sadness; baby>infant; background>heritage; backpack>camera; backpack>dialect; backpack>hand; backpack>handbag; backpack>hip; backpack>laptop;
backpack>luggage; backpack>plastic; backpack>shoulder; backpack>skateboard; backpack>student; backpack>suitcase; backpacker>backpack; backpacker>hostel;
backpacking>backpacker; backup>cd; backup>data; backup>dvd; backup>raid; bacon>beef; bacon>chicken; bacon>fat; bacon>goat; bacon>ham; bacon>pizza; bacon>potato;
bacon>salad; bacon>salt; bacon>sausage; bacon>skin; bacon>teaspoon; bacteria>agriculture; bacteria>antibiotic; bacteria>blood; bacteria>carbon dioxide;
bacteria>carbon monoxide; bacteria>cheese; bacteria>disease; bacteria>dna; bacteria>earth; bacteria>evolution; bacteria>gene; bacteria>genetics; bacteria>habitat;
bacteria>immune system; bacteria>infection; bacteria>medicine; bacteria>nose; bacteria>oxygen; bacteria>plant; bacteria>pollution; bacteria>protein; bacteria>root; bacteria>skin;
bacteria>sphere; bacteria>wildlife; bacteria>wine; bacteria>vinegar; bacteria>virus; bacteria>vitamin; bacteria>yogurt; badge>detective; badge>leather; badge>metal; badge>plastic;
badge>police; badge>uniform; badminton>competition; badminton>leather; badminton>rubber; badminton>table tennis; badminton>tennis; bag>backpack; bag>basket; bag>berry;
bag>cloth; bag>clothing; bag>cookie; bag>fee; bag>hand; bag>handbag; bag>leather; bag>money; bag>paper; bag>purse; bag>shopping; bag>suitcase;
bag>tea; bag>tool; bag>travel; baggage>aeroplane; baggage>clothing; baggage>fashion; baggage>passenger; baggage>souvenir; baggage>suitcase; baggage>tourist;
baggage>transport; baggage>wealth; baggage>vehicle; baker>bakery; baker>bread; baker>cake; baker>employment; baker>fast food; baker>flour; baker>landlord;
baker>loaf; baker>oven; baker>recipe; baker>supermarket; bakery>baker; bakery>bread; bakery>café; bakery>cake; bakery>coffee; bakery>establishment; bakery>flour;
bakery>oven; bakery>retail; bakery>tea; balcony>column; ball>cricket; ball>engineering; ball>football; ball>kitten; ball>puppy; ball>rubber; ball>sphere; ballet>music;
ballet>orchestra; ballet>singing; balloon>density; balloon>gas; balloon>oxygen; balloon>pump; balloon>solution; balloon>stomach; banana>agriculture; banana>archaeology;
banana>bark; banana>carpet; banana>coconut; banana>coffee; banana>cooking; banana>farmer; banana>fruit; banana>ghost; banana>income; banana>mango;
banana>pancake; banana>potato; banana>sand; banana>silk; banana>spirit; banana>sunlight; banana>supermarket; banana>taste; banana>tree; banana>umbrella;
banana>water; banana>vegetable; banana>virus; band>strap; bang>exclamation mark; bank>account>credit card; bank>check; bank>cheque; bank>credit card; bank>debit card;
bank>debt; bank>economy; bank>finance; bank>interest; bank>loan; bank>money; bank>overdraft; banker>bank; banking>bank; barbecue>beef; barbecue>caserole;
barbecue>chicken; barbecue>goat; barbecue>pig; barbecue>pork; barbecue>sausage; barbecue>vinegar; barber>beard; barber>comb; barber>dentist; barber>hairdresser;
barber>mirror; barber>razor; barber>surgery; barber>vocation; bargain>contract; bark>aspirin; bark>backpack; bark>disease; bark>famine; bark>mango; bark>pine; bark>potato;
bark>root; bark>rope; bark>spice; bark>tree; bark>vine; bark>wood; barn>cattle; barn>door; barn>farm; barn>harvest; barn>horse; barn>loft; barn>problem; barn>saddle;
barn>shed; barn>stable; barn>stall; barn>straw; barn>trousers; baseball>basketball; baseball>baseball; baseball>cricket; baseball>ice hockey; baseball>statistics; basement>central heating;
basement>coal; basement>door; basement>house; basement>industrialization; basement>leak; basement>renovation; basement>slope; basement>spade; basement>storey;
basement>toadal; basement>wine; basket>art; basket>laundry; basket>material; basketball>disability; basketball>peach; basketball>playground; basketball>wheelchair;
bat>animal; bat>bird; bat>blood; bat>death; bat>disease; bat>ear; bat>evolution; bat>eye; bat>fish; bat>flesh; bat>flight; bat>flower; bat>fog; bat>food; bat>fruit; bat>genetics;
bat>ghost; bat>hero; bat>hunting; bat>insect; bat>mammal; bat>mosquito; bat>novel; bat>owl; bat>rabbit; bat>skeleton; bat>skin; bat>soup; bat>toe; bat>tongue; bat>vein;
bat>wife; bat>wolf; bat>wolf; bathroom>carpet; bathroom>comb; bathroom>heater; bathroom>mat; bathroom>mirror; bathroom>shower; bathroom>sink; bathroom>soap;
bathroom>toilet; bathroom>towel; bathroom>aircraft; battle>army; battle>castle; battle>combat; battle>earth; battle>geography; battle>helicopter; battle>information; battle>politics;
battle>radio; battle>sea; battle>space; battle>strategy; battle>tank; battle>transport; battle>war; battle>weapon; bay>anchor; bay>coast; bay>fish; bay>fishing; bay>lake; bay>pond;
bay>port; bay>sea; bay>trade; beach>coast; beach>erosion; beach>sand; beach>shore; beach>waste; beach>wave; beach>bone; beach>evolution; beach>nostril; beach>owl;
beak>reptile; beak>shield; beak>skull; beak>tooth; bean>bacteria; bean>cabbage; bean>cholesterol; bean>iron; bean>oil; bean>pea; bean>protein; bean>seed; bean>vinegar;
bear>animal; bear>ant; bear>bicycle; bear>continent; bear>dna; bear>dog; bear>extinction; bear>fishing; bear>habitat; bear>hug; bear>hunting; bear>insect; bear>mammal;
bear>nickname; bear>polar bear; bear>species; bear>stock market; bear>tiger; bear>tribe; bear>wolf; beard>barber; beard>boxing; beard>cheek; beard>chin; beard>evolution;
beard>goat; beard>government; beard>hair; beard>honour; beard>moustache; beard>neck; beard>philosopher; beard>politics; beard>perception; beard>religion; beard>scissors;
beauty>charisma; beauty>elegance; beauty>harmony; beauty>idea; beauty>integrity; beauty>intelligence; beauty>nature; beauty>perception; beauty>pleasure; beauty>politeness;
beauty>ratio; bed>baby; bed>blanket; bed>bronze; bed>clothing; bed>curtain; bed>door; bed>duvet; bed>fur; bed>furniture; bed>gold; bed>hair; bed>hospital; bed>infant;
bed>iron; bed>leaf; bed>leather; bed>linen; bed>marriage; bed>metal; bed>parliament; bed>pillow; bed>silk; bed>silver; bed>skin; bed>sleep; bed>straw; bed>throne; bed>velvet;
bed>wood; bed>wool; bedroom>apartment; bedroom>bathroom; bedroom>bookcase; bedroom>carpet; bedroom>chest of drawers; bedroom>room; bedroom>wardrobe;
bee>advertising; bee>ant; bee>banana; bee>butterfly; bee>coconut; bee>disease; bee>evolution; bee>flower; bee>fly; bee>gardener; bee>honey; bee>insect; bee>mosquito;
bee>plant; bee>predator; bee>protein; bee>rice; bee>society; bee>wasp; bee>wood; beef>bacteria; beef>barbecue; beef>brain; beef>cattle; beef>cooking; beef>curry;
beef>economics; beef>grain; beef>heart; beef>iron; beef>kidney; beef>leather; beef>liver; beef>meat; beef>milk; beef>muscle; beef>oven; beef>pork; beef>reproduction;

beef-sauce; beef>sausage; beef>steak; beef>supermarket; beef>vinegar; beer>antibiotic; beer>bread; beer>cancer; beer>carbon dioxide; beer>cholesterol; beer>fat; beer>manufacturing; beer>protein; beer>soft drink; beer>stroke; beer>sugar; beer>tea; beer>thermometer; belief>advertising; belief>faith; belief>idea; belief>knowledge; belief>popinon; belief>proposition; belief>religion; belief>suggestion; belief>truth; benefit>consideration; benefit>economics; benefit>insurance; benefit>law; benefit>system; benefit>well-being; berry>banana; berry>cherry; berry>fruit; berry>grape; berry>lemon; berry>olive; berry>peach; berry>poison; berry>potato; berry>seed; berry>skin; berry>strawberry; berry>tomato; bestseller>advertising; bestseller>book; bestseller>chart; bestseller>fiction; bestseller>film; bestseller>marketing; bestseller>novel; bestseller>professor; bestseller>publicity; bestseller>publisher; bestseller>retailer; bet>gambling; bias>audience; bias>employment; bias>government; bias>journalist; bias>ownership; bias>preference; bias>prejudice; bias>racism; bicycle>carbon dioxide; bicycle>cycling; bicycle>hand; bicycle>mail; bicycle>recreation; bicycle>sport; bicycle>transport; bicycle>vehicle; bike>bicycle; bikini>breast; bikini>cotton; bikini>fashion; bikini>shoulder; bikini>surfing; bikini>thigh; bikini>tights; bill>back; bill>menu; bill>police; bill>poster; biography>literacy; biography>priest; biography>saint; biology>aggression; biology>agriculture; biology>animal; biology>bacteria; biology>cancer; biology>climate; biology>climate change; biology>dna; biology>earth; biology>ecology; biology>energy; biology>essay; biology>evolution; biology>food; biology>gene; biology>genetics; biology>habitat; biology>human; biology>immune system; biology>life; biology>medicine; biology>plant; biology>population; biology>protein; biology>psychology; biology>species; birds>adaptation; birds>agriculture; birds>bacteria; birds>beak; birds>blindness; birds>cat; birds>chicken; birds>crocodile; birds>dinosaur; birds>dog; birds>dolphin; birds>duck; birds>eagle; birds>ear; birds>evolution; birds>extinction; birds>feather; birds>heart; birds>hunting; birds>insect; birds>kidney; birds>owl; birds>parrot; birds>penguin; birds>predator; birds>reptile; birds>season; birds>snake; birds>sound; birds>sun; birds>swan; birds>tuna; birds>wing; birth>baby; birth>birthday; birth>death; birth>health care; birth>horizon; birth>life; birth>mother; birth>nerve; birth>offspring; birth>pregnancy; birth>sky; birth>sun; birth>surgery; birth>twin; birth>virgin; birthday>anniversary; birthday>cake; birthday>holiday; biscuit>bean; biscuit>breakfast; biscuit>chocolate; biscuit>cookie; biscuit>cooking; biscuit>dictionary; biscuit>digestion; biscuit>flour; biscuit>sandwich; biscuit>sausage; bit>communication; bit>credit card; bit>dna; bit>information; bit>traffic light; bite>animal; bite>bat; bite>cat; bite>dog; bite>fish; bite>food; bite>infection; bite>mouth; bite>rabbit; bite>wildlife; bite>wolf; bite>wound; black>atom; black>blackmail; black>cherry; black>chess; black>cliché; black>coal; black>cookie; black>crime; black>darkness; black>death; black>devil; black>drawing; black>elegance; black>evil; black>god; black>heat; black>ink; black>iron; black>leopard; black>light; black>night; black>oak; black>peach; black>physics; black>sin; black>tree; black>white; blackboard>paint; blackboard>writing; blackmail>gossip; blackmail>robbery; blade>area; blade>bone; blade>butter; blade>chef; blade>force; blade>hammer; blade>knife; blade>leather; blade>machine; blade>pizza; blade>plastic; blade>predator; blade>pressure; blade>prey; blade>steel; blade>stone; blade>sword; blade>tool; blade>toughness; blade>weapon; blame>abuse; blame>accident; blame>anxiety; blame>crime; blame>denial; blame>hierarchy; blame>organization; blame>praise; blame>propaganda; blame>remorse; blame>safety; blame>shame; blanket>cotton; blanket>duvet; blanket>firefighter; blanket>linen; blanket>picnic; blanket>saddle; blanket>sleep; blanket>soil; blanket>wool; blends>dictionary; blends>root; blends>smog; blends>suffix; blindness>calculator; blindness>camera; blindness>coin; blindness>elephant; blindness>euro; blindness>mammal; blindness>mobile phone; blindness>poverty; blindness>rabbit; blindness>tennis; blindness>thermometer; blindness>torture; blister>blood; blister>friction; blister>skin; blog>advertising; blog>brand; blog>business; blog>corporation; blog>family; blog>forgery; blog>journalist; blog>marketing; blog>mobile phone; blog>newspaper; blog>university; blog>web page; blood>web site; blogger>blog; blood>ancestor; blood>animal; blood>antibiotic; blood>blue; blood>breath; blood>carbon dioxide; blood>carbon monoxide; blood>copper; blood>film; blood>heart; blood>heat; blood>immune system; blood>infection; blood>injury; blood>insect; blood>iron; blood>kidney; blood>litre; blood>liver; blood>lung; blood>meat; blood>mosquito; blood>protein; blood>tobacco; blood>water; blood>vein; blood>virus; blue>atmosphere; blue>basketball; blue>boy; blue>cold; blue>colour; blue>cover; blue>denim; blue>green; blue>ice; blue>ice hockey; blue>ink; blue>jeans; blue>laser; blue>oxygen; blue>pink; blue>police; blue>red; blue>sadness; blue>sea; blue>sky; blue>sunrise; blue>sunset; blue>truth; blue>water; blue>winter; blue>yellow; board game>cd; board game>chess; board game>dice; board game>diplomacy; board game>dvd; board game>email; board game>game; board game>jargon; board game>lion; board game>luck; board game>material; board game>puzzle; board game>scenario; board game>strategy; board game>symbol; board game>website; board game>video game; boat>aluminium; boat>density; boat>lake; boat>navy; boat>sail; boat>ship; boat>yacht; body>arm; body>burial; body>death; body>disability; body>disease; body>health; body>human; body>insect; body>materialism; body>meat; body>neck; body>spirit; bomb>air force; bomb>bomber; bomb>bridge; bomb>civilian; bomb>clock; bomb>construction; bomb>explosion; bomb>friction; bomb>heat; bomb>mining; bomb>missile; bomb>parachute; bomb>port; bomb>port; bomb>railway; bomb>remote control; bomb>rocket; bomb>runway; bomb>temperature; bomb>train; bomb>transport; bombing>bomb; bond>guarantee; bone>acid; bone>ankle; bone>beak; bone>birth; bone>brain; bone>coral; bone>disease; bone>evolution; bone>exercise; bone>fat; bone>foot; bone>heart; bone>human; bone>joint; bone>nerve; bone>offspring; bone>protein; bone>rib; bone>skeleton; bone>skull; bone>structure; book>author; book>bookcase; book>business; book>cd-rom; book>controversy; book>desk; book>diary; book>dictionary; book>dvd; book>entertainment; book>fiction; book>homework; book>ink; book>leather; book>library; book>linen; book>literacy; book>literature; book>magazine; book>map; book>market; book>meeting; book>music; book>news paper; book>notebook; book>novel; book>paper; book>photograph; book>prayer; book>publisher; book>punctuation; book>scientist; book>software; book>student; book>textbook; book>word; book>writer; bookcase>book; bookcase>cupboard; bookcase>furniture; bookcase>iron; bookcase>leather; bookcase>library; bookcase>oak; bookcase>steel; booking>arrest; booking>loan; booking>running; booking>tourism; booklet>book; bookmark>book; bookmark>fabric; bookshelf>bookcase; boost>theft; boost>ankle; boost>blister; boost>fisherman; boost>foot; boost>gift; boost>ice skating; boost>knee; boost>shoe; boost>skiing; boost>snowboarding; boost>sock; boost>sport; boost>sweat; border>airport; border>alcohol; border>barrier; border>commerce; border>continent; border>export; border>forest; border>geography; border>government; border>immigration; border>import; border>lake; border>ocean; border>passport; border>port; border>river; border>leadership; boss>management; boss>supervisor; bottle>alcohol; bottle>beer; bottle>cod; bottle>gas; bottle>glass; bottle>ink; bottle>jar; bottle>liquid; bottle>medicine; bottle>milk; bottle>perfume; bottle>plastic; bottle>pressure; bottle>retailer; bottle>rubber; bottle>shampoo; bottle>soft drink; bottle>water; bottle>wine; bottom>contradiction; boundary>border; bow>elbow; bow>ribbon; bowl>archaeology; bowl>art; bowl>food; bowls>glass; bowl>metal; bowl>plastic; bowl>salad; bowls>wine; bowl>wood; box>carriage; box>circle; box>gift; box>globalization; box>letter; box>match; box>metal; box>pizza; box>plural; box>post office; box>rectangle; box>wood; boxing>fiction; boy>angel; boy>boyfriend; boy>child; boy>choir; boy>funeral; boys>furniture; boys>gender; boy>girl; boy>goat; boy>human; boy>infant; boy>insult; boy>male; boy>man; boy>nickname; boy>pizza; boy>portrait; boy>racist; boy>sex; boy>sheep; boys>slang; boy>soldier; boy>teenager; boy>toddler; boy>torch; boy>trainee; boy>youth; boyfriend>girlfriend; boyfriend>marriage; boyfriends>wedding; bracelet>ankle; bracelet>archaeology; bracelet>boot; bracelet>cloth; bracelet>hospital; bracelet>leather; bracelet>manufacturing; bracelet>metal; bracelet>necklace; bracelet>plastic; bracelet>wood; bracket>chemistry; bracket>concentration; bracket>full stop; bracket>punctuation; bracket>synonym; brain>alcohol; brain>artificial intelligence; brain>attention; brain>digestion; brain>dog; brain>elephant; brain>evolution; brain>gene; brain>horse; brain>human; brain>insect; brain>learning; brain>medicine; brain>mind; brain>motivation; brain>philosophy; brain>psychology; brain>rat; brain>shark; brain>stroke; brain>strake; brain>anchor; brake>friction; brake>advertising; brake>vehicle; brake>wheel; branch>cherry; branch>collocation; branch>metaphor; branch>oak; branch>root; branch>synonym; branch>tree; branch>walking; branch>business; branch>commodity; brands>factory; brands>fashion; brands>industrialization; brands>logo; brands>luggage; brands>marketing; brands>personality; brands>radio; brands>slogan; brands>soap; brands>television; brands>tire; brands>aluminium; brands>bacteria; brands>brass; brands>bronze; brands>coal; brands>coin; brands>copper; brands>dice; brands>friction; brands>glass; brands>iron; brands>lead; brands>metal; brands>orchestra; brands>recycling; brands>tin; brands>trumpet; brands>turkey; bravery>courage; bread>baker; bread>beer; bread>biscuit; bread>bus; bread>carbon dioxide; bread>cereal; bread>cream; bread>fat; bread>flour; bread>food; bread>fruit; bread>frying pan; bread>grape; bread>meat; bread>metaphor; bread>milk; bread>money; bread>onion; bread>oven; bread>pancake; bread>pizza; bread>plastic; bread>protein; bread>ratio; bread>rice; bread>sandwich; bread>sausage; bread>seed; bread>soup; bread>spice; bread>sugar; bread>synonym; bread>temperature; bread>toast; bread>water; bread>vegetable; bread>wheat; bread>wine; break>burglary; breakfast>bacon; breakfast>bun; breakfast>butter; breakfast>cereal; breakfast>cheese; breakfast>chocolate; breakfast>coffee; breakfast>ham; breakfast>honey; breakfast>jam; breakfast>lunch; breakfast>mango; breakfast>meat; breakfast>mushroom; breakfast>pancake; breakfast>sausage; breakfast>sweet; breakfast>tea; breakfast>toast; breakfast>tomato; breakfast>yogurt; breakthrough>insight; breast>beauty; breast>cancer; breast>female; breast>infant; breast>milk; breast>nose; breast>obesity; breast>pregnancy; breast>religion; breast>vein; breed>generation; breed>genetics; breed>offspring; breed>plant; breed>population; breed>species; breeze>wind; bribe>bribery; bribery>corporation; bribery>cricket; bribery>donation; bribery>duty; bribery>funding; bribery>gambling; bribery>gift; bribery>medication; bribery>money; bribery>patient; bribery>police; bribery>policy; bribery>politician; bribery>privilege; bribery>property; bribery>referee; bribery>sponsorship; brick>chimney; brick>concrete; brick>glass; brick>inch; brick>millimetre; brick>water; brick>wood; bride>death; bride>handbag; bride>red; bride>red; bride>spouse; bride>virgin; bride>brick; bride>laser; bride>stream; bridge>road; bridge>suicide; bridge>tunnel; bridge>turkey; bridge>valley; broadband>music; broadband>radio; broadband>telecommunications; broadband>telephone; broadband>television; broadband>video; broccoli>bacteria; broccoli>branch; broccoli>cabbage; broccoli>cancer; broccoli>virus; brochure>paper; bronze>aluminium; bronze>blade; bronze>brass; bronze>coin; bronze>copper; bronze>glitter; bronze>friction; bronze>gold; bronze>guitar; bronze>hammer; bronze>iron; bronze>medal; bronze>oak; bronze>piano; bronze>silver; bronze>steel; bronze>tin; bronze>toughness; brother>sibling; brother-in-law>husband; brother-in-law>sibling; brother-in-law>sister-in-law; brother-in-law>spouse; brown>autism; brown>bear; brown>black; brown>chocolate; brown>coffee; brown>dna; brown>humility; brown>ink; brown>iron; brown>oak; brown>rat; brown>red; brown>skin; brown>stone; brown>yellow; bruise>blisters; bruise>blood; bruise>blue; bruise>bone; bruise>brain; bruise>death; bruise>head; bruise>heart; bruise>lung; bruise>muscle; bruise>nerve; bruise>pain; bruise>purple; bruise>skin; bruise>surgery; bruise>toenail; brush>artist; brush>camel; brush>comb; brush>copper; brush>goat; brush>hair; brush>ink; brush>paint; brush>painting; brush>plastic; brush>pony; brush>steel; brush>toothbrush; brush>wood; bucket>beach; bucket>bronze; budget>expenses; budget>government; budget>income; budget>project; bug>insect; building>aircraft; building>architect; building>architecture; building>construction; building>document; building>earthquake; building>electrician; building>engineering; building>escalator; building>fire; building>funding; building>home; building>house; building>human; building>professional; building>security; building>ship; building>storey; building>structure; building>technology; building>telecommunications; building>transport; bulb>food; bulb>garlic; bulb>leaf; bulb>onion; bulb>root; bulb>camel; bulb>cattle; bulb>cow; bulb>elephant; bulb>god; bulb>male; bulb>sheep; bulb>wheat; bullet>base; bullet>brass; bullet>copper; bullet>explosive; bullet>gas; bullet>gram; bullet>lead; bullet>riot; bullet>steel; bullet>tin; bullet>weapon; bun>bread; bun>butter; bun>flour; bun>jam; bun>milk; bun>sugar; bureaucracy>corporation; bureaucracy>transportation; bureaucracy>writing; burglary>crime; burglary>dog; burglary>rape; burglary>theft; burglary>vandalism; burial>accident; burial>ancestor; burial>animal; burial>archaeology; burial>bacteria; burial>banana; burial>bone; burial>butcher; burial>cat; burial>cemetery; burial>child; burial>construction; burial>crime; burial>cross; burial>culture; burial>dog; burial>earthquake; burial>elephant; burial>flood; burial>funeral; burial>infant; burial>marriage; burial>murder; burial>ocean; burial>oven; burial>pet; burial>police; burial>religion; burial>ritual; burial>starvation; burial>suicide; burial>temple; burial>terrorism; burial>tourism; bus station>barrier; bus station>bus; bus station>bus stop; bus station>wheelchair; bus stop>bus station; bus stop>dstin; bus stop>lighting; bus stop>mobile phone; bus stop>public transport; bus>bicycle; bus>bus; bus>bus stop; bus>camel; bus>carriage; bus>fair; bus>paint; bus>parade; bus>passenger; bus>playground; bus>police officer; bus>procession; bus>scrap; bus>sightseeing; bus>tour guide; bus>truck; bus>wheelchair; business>advertising; business>agriculture; business>bank; business>banking; business>capitalism; business>commerce; business>company; business>consumer; business>corporation; business>customer; business>economics; business>economy; business>finance; business>government; business>home; business>industry; business>insurance; business>investment; business>management; business>manufacturer; business>manufacturing; business>marketing; business>mining; business>money; business>organization; business>partnership; business>restaurant; business>retail; business>stock market; business>trade; business>transport; business>transportation; business>treaty; butcher>culture; butcher>manufacturing; butcher>nationality; butcher>retail; butcher>supermarket; butcher>vocation; butcher>acid; butcher>beef; butcher>cake; butcher>cattle; butcher>cheese; butcher>cholesterol; butcher>cookie; butcher>cooking; butcher>cream; butcher>dessert; butcher>fat; butcher>goat; butcher>herb; butcher>ice; butcher>mammal; butcher>milk; butcher>pastry; butcher>peasant; butcher>pie; butcher>potato; butcher>protein; butcher>sauce; butcher>sheep; butcher>spice; butcher>sugar; butcher>tea; butcher>teaspoon; butcher>wine; butcher>vinegar; butcher>yellow; butterfly>animal; butterfly>bee; butterfly>head; butterfly>insect; butterfly>predator; butterfly>species; button>antique; button>archaeology; button>brass; button>clothing; button>copper; button>drug; button>fabric; button>fashion; button>ink; button>linen; button>memorial; button>painting; button>plastic; button>sculpture; button>shirt; button>wood; buyer>asset; buyer>consideration; buyer>customer; cabbage>broccoli; cabbage>cash; cabbage>pea; cabbage>selection; cabbage>species; cabbage>tobacco; cabbage>wheat; cabin>cottage; cable>cotton; cable>fire; cable>gold; cable>food; cable>rope; cable>silver; cable>tin; cable>vine; cake>anniversary; cake>birthday; cake>bread; cake>butter; cake>chocolate; cake>dessert; cake>extract; cake>flour; cake>foam; cake>goat; cake>milk; cake>pastry; cake>pie; cake>poet; cake>strawberry; cake>sugar; cake>water; cake>wedding; calculator>calculator; calculator>computer; calculator>memory; calculator>statistics; calculator>student; calendar>ad; calendar>agriculture; calendar>business; calendar>century; calendar>cheque; calendar>clock; calendar>day; calendar>decade; calendar>family; calendar>judge; calendar>lawyer; calendar>millennium; calendar>month; calendar>night; calendar>season; calendar>sun; calendar>sunrise; calendar>sunset; calendar>tide; calendar>time; calendar>week; calendar>year; calf>abortion; calf>auction; calf>camel; calf>cattle; calf>cow; calf>dolphin; calf>elephant; calf>farming; calf>giraffe; calf>human; calf>mammal; calf>whale;

camel-animal; camel-body; camel-butter; camel-ice cream; camel-immune system; camel-iron; camel-kidney; camel-mammal; camel-milk; camel-year; camel-yogurt; camera-architecture; camera-digital camera; camera-image; camera-light; camera-photograph; camera-photography; camera-video; camp-campsite; camp-campus; camp-cottage; campaign-video game; camping-air conditioning; camping-aircraft; camping-backpack; camping-bear; camping-blanket; camping-boot; camping-campsite; camping-candle; camping-civilization; camping-climbing; camping-cold; camping-cotton; camping-electricity; camping-family; camping-fishing; camping-food; camping-friendly; camping-frying pan; camping-hammer; camping-heat; camping-homelessness; camping-insect; camping-raincoat; camping-recreation; camping-rope; camping-safety; camping-snow; camping-social networking; camping-tent; camping-toilet; camping-towel; camping-water; camping-wind; camping-woodland; camping-wool; campsite-camping; campsite-electricity; campsite-hotel; campsite-picnic; campsite-road; campsite-shower; campsite-tent; campsite-vehicle; campus-college; campus-hospital; campus-lecture; campus-library; campus-university; can-toilet; canal-agriculture; canal-bridge; canal-globalization; canal-historian; canal-infrastructure; canal-lake; canal-ocean; canal-river; canal-ship; canal-telecommunications; canal-tunnel; cancer-abortifacient; cancer-alcohol; cancer-asthma; cancer-bacteria; cancer-blood; cancer-bone; cancer-coffee; cancer-cough; cancer-crab; cancer-diagnosis; cancer-disease; cancer-dna; cancer-evolution; cancer-fat; cancer-fever; cancer-gene; cancer-immune system; cancer-infection; cancer-kidney; cancer-liver; cancer-lung; cancer-mobile phone; cancer-nerve; cancer-obesity; cancer-optimism; cancer-probability; cancer-protein; cancer-radiation; cancer-rib; cancer-salt; cancer-smoking; cancer-sun; cancer-surgery; cancer-symptom; cancer-tobacco; cancer-vaccine; cancer-virus; cancer-vitamin; cancer-x-ray; candidate-award; candidate-ceremony; candidate-debate; candidate-election; candidate-law; candidate-nomination; candidate-office; candidate-official; candidate-white; candle-chemical; candle-consumer; candle-fire; candle-flame; candle-fuel; candle-honey; candle-lead; candle-light; candle-oxygen; candle-property; candle-reach; candle-regulation; candle-religion; candle-risk; candle-safety; candle-scent; candle-standard; candle-time; capacity-volume; capital-capital letter; capital-capitalism; capitalism-asset; capitalism-cattle; capitalism-coal; capitalism-commerce; capitalism-consumer; capitalism-corporation; capitalism-democracy; capitalism-economics; capitalism-factory; capitalism-globalization; capitalism-government; capitalism-history; capitalism-incentive; capitalism-inflation; capitalism-infrastructure; capitalism-investor; capitalism-market; capitalism-monopoly; capitalism-peasant; capitalism-policy; capitalism-recession; capitalism-slavery; capitalism-socialism; capitalism-subsidy; capitalism-tax; capitalism-trade; capitalism-unemployment; capitalism-well-being; captain-commander; carbon dioxide-acid; carbon dioxide-alcohol; carbon dioxide-atom; carbon dioxide-bacteria; carbon dioxide-beer; carbon dioxide-carbon; carbon dioxide-carbon monoxide; carbon dioxide-climate change; carbon dioxide-coffee; carbon dioxide-coral; carbon dioxide-energy; carbon dioxide-fuel; carbon dioxide-gas; carbon dioxide-global warming; carbon dioxide-grape; carbon dioxide-iron; carbon dioxide-life; carbon dioxide-light; carbon dioxide-oxygen; carbon dioxide-plant; carbon dioxide-pressure; carbon dioxide-protein; carbon dioxide-soft drink; carbon dioxide-sugar; carbon dioxide-water; carbon dioxide-vein; carbon dioxide-whisky; carbon dioxide-wine; carbon dioxide-volcano; carbon dioxide-volume; carbon dioxide-wood; carbon footprint-carbon; carbon footprint-carbon dioxide; carbon footprint-coal; carbon footprint-food; carbon footprint-global warming; carbon footprint-oil; carbon monoxide-carbon; carbon monoxide-carbon dioxide; carbon monoxide-chemist; carbon monoxide-coal; carbon monoxide-iron; carbon monoxide-headache; carbon monoxide-heart; carbon monoxide-iron; carbon monoxide-oxygen; carbon monoxide-ozone; carbon monoxide-pressure; carbon monoxide-steam; carbon monoxide-volcano; carbon-acid; carbon-alcohol; carbon-antibiotic; carbon-art; carbon-atmosphere; carbon-atom; carbon-brush; carbon-carbon dioxide; carbon-carbon footprint; carbon-carbon monoxide; carbon-civilization; carbon-coal; carbon-commodity; carbon-cotton; carbon-crystal; carbon-density; carbon-diamond; carbon-dna; carbon-drawing; carbon-earth; carbon-electricity; carbon-electronics; carbon-fat; carbon-fuel; carbon-glass; carbon-gold; carbon-gram; carbon-human; carbon-ink; carbon-iron; carbon-kitchen; carbon-lead; carbon-leather; carbon-linen; carbon-metal; carbon-oxygen; carbon-pencil; carbon-planet; carbon-plastic; carbon-protein; carbon-pyramid; carbon-rubber; carbon-second; carbon-silk; carbon-sphere; carbon-star; carbon-sugar; carbon-sun; carbon-window; carbon-wool; carbon-writing; carbon-x-ray; card-debit card; card-postcard; care-health care; career-education; career-person; career-profession; carelessness-negligence; cargo-commerce; cargo-customs; cargo-delivery; cargo-grain; cargo-machinery; cargo-manufacturing; cargo-meat; cargo-oil; cargo-port; cargo-produce; cargo-salt; cargo-scrap; cargo-shoe; cargo-supermarket; cargo-terrorist; cargo-toy; cargo-transport; cargo-truck; cargo-van; carnival-coconut; carnival-fair; carnival-mask; carnival-parade; carnival-plan; carnival-ski; carnival-witch; carpet-cloth; carpet-commerce; carpet-cotton; carpet-linen; carpet-mat; carpet-nature; carpet-sewing; carpet-silk; carpet-turkey; carpet-wool; carriage-bride; carriage-bus; carriage-groom; carriage-horse; carriage-pony; carriage-sightseeing; carriage-tourism; carriage-turkey; carrots-fair; carrot-fruit; carrot-jam; carrot-onion; carrot-snack; carrot-soup; carrot-sugar; carrot-supermarket; cartoon-animation; cartoon-drawing; cartoon-illustration; cartoon-irony; cartoon-painting; cartoon-paper; case-bookcase; case-box; case-suitcase; cash-bank; cash-coin; cash-currency; cash-inflation; cash-money; casserole-beer; casserole-flour; casserole-oven; casserole-pasta; casserole-potato; casserole-rice; casserole-wine; cast-archaeology; cast-fantasy; castle-archaeology; castle-headquarters; castle-palace; casualty-disaster; cat-animal; cat-aspirin; cat-bird; cat-camel; cat-dream; cat-fur; cat-giraffe; cat-grass; cat-kitten; cat-leopard; cat-mammal; cat-paw; cat-pet; cat-rat; cat-scissors; cat-tongue; catastrophe-disaster; catering-business; catering-concert; catering-drink; catering-wedding; catering-vegetarian; catering-vehicle; cathedral-chapel; cathedral-earth; cathedral-heaven; cathedral-sculpture; cattle-agriculture; cattle-animal; cattle-beef; cattle-blood; cattle-bull; cattle-butter; cattle-calf; cattle-camel; cattle-cheese; cattle-clothing; cattle-contract; cattle-elf; cattle-fence; cattle-fuel; cattle-global warming; cattle-heart; cattle-herb; cattle-horse; cattle-kidney; cattle-leather; cattle-liver; cattle-mammal; cattle-meat; cattle-milk; cattle-plural; cattle-shoe; cattle-species; cattle-sport; cattle-stomach; cattle-tick; cattle-transport; cattle-turkey; cattle-vegetation; cattle-whale; cattle-yogurt; cave-bat; cd player-cd; cd player-computer; cd player-consumer; cd player-dj; cd player-sound; cd-rom-aluminium; cd-rom-dvd; cd-rom-laser; cd-rom-minute; cd-rom-plastic; cd-rom-second; cd-rom-software; cd-rom-video game; ceiling-cathedral; ceiling-concrete; ceiling-system; celebration-festival; celebration-holiday; celebration-party; celebrity-entertainer; celebrity-fragrance; celebrity-leader; celebrity-medication; celebrity-monster; celebrity-nightclub; celebrity-pottery; celebrity-presenter; celebrity-referee; celebrity-reporter; celebrity-social networking; celebrity-soft drink; celebrity-spy; cell-mobile phone; cellar-basement; cello-disco; cello-guitar; cello-hip-hop; cello-jazz; cello-length; cello-orchestra; cello-piano; cello-plastic; cello-steel; cello-violin; cello-volume; cemetery-angel; cemetery-brick; cemetery-burial; cemetery-concrete; cemetery-crime; cemetery-culture; cemetery-flower; cemetery-funeral; cemetery-grass; cemetery-lawn; cemetery-legend; cemetery-legislation; cemetery-map; cemetery-metal; cemetery-monument; cemetery-profession; cemetery-religion; cemetery-skeleton; cemetery-timber; cemetery-tomb; cemetery-toy; cemetery-vase; cent-century; centimetre-equal; centimetre-inch; centimetre-length; centimetre-litre; centimetre-metre; centimetre-millimetre; central heating-air conditioning; central heating-climate; central heating-dishwasher; central heating-grape; central heating-heating; central heating-pump; central heating-washing machine; century-decade; century-millennium; century-year; cereal-agriculture; cereal-fat; cereal-fruit; cereal-protein; cereal-rice; cereal-wheat; cereal-vitamin; ceremony-battle; ceremony-birthday; ceremony-burial; ceremony-dance; ceremony-death; ceremony-funeral; ceremony-gift; ceremony-procession; ceremony-retirement; ceremony-ritual; ceremony-theatre; ceremony-wedding; certainty-belief; certainty-doubt; certainty-instinct; certainty-paradox; certainty-philosophy; certainty-uncertainty; chain-dimension; chain-liberty; chain-toilet; chair-cushion; chair-furniture; chair-leather; chair-oak; chair-privacy; chair-public transport; chair-saddle; chair-seat; chair-throne; chair-wheelchair; chair-wood; champagne-carbon dioxide; champion-championship; champion-competition; champion-victory; championship-boxing; championship-champion; championship-sport; championships-tennis; chance-luck; chance-probability; chancellor-parliament; chancellor-prime minister; chancellor-solicitor; chancellor-title; change-coin; channel-canal; chapel-cathedral; chapel-college; chapel-hospital; chapel-palace; chapel-prayer; chapel-prison; chapel-room; chapel-ship; chapel-worship; characteristic-entity; characteristic-property; charge-debit; charm-charisma; chart-data; chart-diagram; chart-genetics; chart-graphics; chart-map; chart-number; chart-percentage; chart-symbol; chat-cat; chat-conversation; check-check; check-chin; check-dna; check-ear; check-face; check-individual; check-jaw; check-mammal; check-mouth; check-species; cheerfulness-happiness; cheese-acid; cheese-agriculture; cheese-butter; cheese-cattle; cheese-cow; cheese-fat; cheese-fortnight; cheese-garlic; cheese-goat; cheese-headache; cheese-herb; cheese-legend; cheese-milk; cheese-nightmare; cheese-pizza; cheese-protein; cheese-rash; cheese-sheep; cheese-spice; cheese-vinegar; cheese-world; chef-butcher; chef-fish; chef-kitchen; chef-meat; chef-profession; chef-salad; chef-sauce; chef-vegetable; chemist-alcohol; chemist-atom; chemist-chemistry; chemist-fire; chemist-glass; chemist-gold; chemist-iron; chemist-medication; chemist-pharmacist; chemist-physics; chemist-scientist; chemist-structure; chemistry-acid; chemistry-atom; chemistry-biology; chemistry-carbon; chemistry-carbon dioxide; chemistry-concentration; chemistry-concept; chemistry-crystal; chemistry-density; chemistry-diamond; chemistry-drug; chemistry-electricity; chemistry-energy; chemistry-experiment; chemistry-force; chemistry-gas; chemistry-genetics; chemistry-geology; chemistry-heat; chemistry-hypothesis; chemistry-iron; chemistry-laboratory; chemistry-liquid; chemistry-matter; chemistry-observation; chemistry-oxygen; chemistry-particle; chemistry-physics; chemistry-pressure; chemistry-solution; chemistry-structure; chemistry-temperature; chemistry-tin; chemistry-volume; cheque-cash; cheque-credit card; cheque-debit card; cheque-drawer; cheque-payment; cherry-flower; cherry-fruit; cherry-turkey; chess-aggression; chess-board game; chess-dice; chess-intelligence; chess-knowledge; chess-mobile phone; chess-perception; chess-drawers-bedroom; chess-drawers-clothing; chess-drawers-furniture; chess-drawers-mirror; chess-drawers-oak; chess-drawers-underwear; chess-drawers-wood; chess-breast; chess-cancer; chess-cough; chess-digestion; chess-infection; chess-neck; chess-shoulder; chess-stomach; chess-tobacco; chess-x-ray; chewing gum-bacteria; chewing gum-bark; chewing gum-culture; chewing gum-grass; chewing gum-plant; chewing gum-rubber; chewing gum-stomach; chewing gum-tree; chicken-agriculture; chicken-animal; chicken-beard; chicken-bird; chicken-breed; chicken-death; chicken-devil; chicken-extinction; chicken-fast food; chicken-fat; chicken-feather; chicken-god; chicken-leg; chicken-lion; chicken-man; chicken-meat; chicken-pet; chicken-pig; chicken-pork; chicken-pottery; chicken-recipe; chicken-silk; chicken-silk; chicken-stomach; chicken-theatre; chicken-tick; chicken-wedding; chicken-vegetarian; chicken-woman; child-abortion; child-birth; child-childhood; child-daughter; child-human; child-infancy; child-law; child-son; childhood-birth; childhood-cat; childhood-child; childhood-culture; childhood-historian; childhood-human rights; childhood-infant; childhood-innocence; childhood-jail; childhood-park; childhood-playground; childhood-television; childhood-toddler; childhood-violin; chill-temperature; chimney-castle; chimney-central heating; chimney-concrete; chimney-density; chimney-earthquake; chimney-fireplace; chimney-fuel; chimney-lead; chimney-mobile phone; chimney-pressure; chimney-smoke; chimney-tv; chin-elephant; chin-face; chin-speech; chip-paint; chocolate-cherry; chocolate-cholesterol; chocolate-food; chocolate-obesity; chocolate-sweet; choice-abortion; choice-availability; choice-convenience; choice-economy; choice-emotion; choice-feeling; choice-image; choice-nutrition; choice-preference; choice-tradition; choir-harmony; choir-opera; choir-orchestra; choir-piano; choir-trumpet; cholesterol-beef; cholesterol-cancer; cholesterol-cheese; cholesterol-chemical; cholesterol-fish; cholesterol-litre; cholesterol-liver; cholesterol-medication; cholesterol-peanut; cholesterol-pork; cholesterol-protein; cholesterol-stroke; cholesterol-suffix; cholesterol-thermometer; cholesterol-water; church-institution; church-religion; cigarette-blend; cigarette-brand; cigarette-cancer; cigarette-debit card; cigarette-prince; cigarette-smoking; cigarette-stroke; cigarette-tobacco; cigarette-turkey; circle-astronomy; circle-circus; circle-curve; circle-equation; circle-gear; circle-science; circle-shape; circle-sphere; circle-triangle; circle-wheel; circulation-circus; circus-bear; circus-bird; circus-clown; circus-elephant; circus-gymnastics; circus-horse; circus-television; city-agriculture; city-bank; city-cathedral; city-civilization; city-communication; city-county; city-city; city-crime; city-democracy; city-empire; city-employment; city-finance; city-firm; city-history; city-homelessness; city-house; city-industry; city-market; city-mayor; city-pollution; city-rain; city-recreation; city-religion; city-suburb; city-sunlight; city-tourist; city-town; city-trade; city-traffic; city-transportation; city-waste; city-village; civilian-country; civilian-crew; civilian-passenger; civilian-terrorist; civilization-agriculture; civilization-architecture; civilization-bureaucracy; civilization-city; civilization-climate change; civilization-complexity; civilization-culture; civilization-currency; civilization-education; civilization-elite; civilization-globalization; civilization-government; civilization-grain; civilization-hierarchy; civilization-law; civilization-literacy; civilization-market; civilization-materialism; civilization-measurement; civilization-money; civilization-ownership; civilization-priest; civilization-religion; civilization-science; civilization-society; civilization-sustainability; civilization-technology; civilization-trade; civilization-transportation; civilization-tribe; civilization-tribute; civilization-university; civilization-writing; claim-proposition; claim-right; clash-battle; class-classroom; class-lesson; classic-adjective; classic-antique; classic-masterpiece; classic-noun; classroom-biology; classroom-book; classroom-chart; classroom-chemistry; classroom-daylight; classroom-desk; classroom-furniture; classroom-gym; classroom-learning; classroom-lecture; classroom-map; classroom-physics; classroom-room; classroom-teacher; classroom-teaching; classroom-tv; classroom-university; clause-gerund; clause-grammar; clause-proposition; clause-verb; cleaner-bucket; cleaner-payment; cleaner-towel; cliché-cartoon; cliché-fact; cliché-idiom; cliché-stereotype; click-animation; click-customer; cliff-channel; cliff-climbing; cliff-coast; cliff-earth; cliff-erosion; cliff-geography; cliff-geology; cliff-mountaintain; cliff-river; cliff-soil; cliff-waterfall; climate change-energy; climate change-fish; climate change-global warming; climate change-island; climate change-satellite; climate change-sun; climate change-sunlight; climate change-weather; climate change-vegetation; climate change-volcano; climate-atmosphere; climate-carbon dioxide; climate-climate change; climate-continent; climate-desert; climate-earth; climate-global warming; climate-history; climate-ice; climate-landscape; climate-mammal; climate-ocean; climate-planet; climate-storm; climate-sun; climate-temperature; climate-thermometer; climate-thunderstorm; climate-weather; climate-wind; climate-world; clinic-abortion; clinic-hospital; clinic-surgery; clinic-x-ray; clock-alarm clock; clock-atom; clock-blindness; clock-central heating; clock-counter; clock-day; clock-earthquake; clock-electronics; clock-energy; clock-feedback; clock-friction; clock-gear; clock-hour; clock-invention; clock-minute; clock-mobile phone; clock-mp3 player; clock-sand; clock-second; clock-time; clock-watch; clock-year; clothes-clothing;

clothing>bandage; clothing>button; clothing>cap; clothing>carpet; clothing>climate; clothing>culture; clothing>diving; clothing>fashion; clothing>film; clothing>fur; clothing>gender; clothing>globalization; clothing>glove; clothing>gymnastics; clothing>handbag; clothing>hat; clothing>hygiene; clothing>infant; clothing>insect; clothing>ironing; clothing>jeans; clothing>laundry; clothing>leather; clothing>painting; clothing>paper; clothing>peer pressure; clothing>photo; clothing>professional; clothing>religion; clothing>shirt; clothing>shorts; clothing>skiing; clothing>skirt; clothing>surfing; clothing>sweater; clothing>television; clothing>tracksuit; clothing>trousers; clothing>t-shirt; clothing>washing machine; clothing>weather; clothing>whale; clothing>wind; clothing>winter; clothing>yellow; cloud>atmosphere; cloud>bacteria; cloud>chemical; cloud>climate; cloud>crystal; cloud>energy; cloud>evolution; cloud>feedback; cloud>fog; cloud>global warming; cloud>habitat; cloud>hail; cloud>light; cloud>lightning; cloud>liquid; cloud>mist; cloud>mountain; cloud>planet; cloud>rain; cloud>salt; cloud>snow; cloud>stable; cloud>summer; cloud>sun; cloud>symbol; cloud>temperature; cloud>thunderstorm; cloud>tornado; cloud>weather; cloud>winter; clown>comedy; clown>donkey; clown>elephant; clown>horse; clown>orchestra; clown>performer; clown>priest; clown>psychology; clown>zebra; club>basketball; club>boxing; club>exercise; club>golf; club>gym; club>secondary school; clue>evidence; clutch>air conditioning; clutch>cable; clutch>friction; clutch>machine; clutch>pressure; coach>coaching; coaching>career; coaching>consultant; coaching>consumer; coaching>discussion; coaching>fashion; coaching>inquiry; coaching>leadership; coaching>marriage; coaching>psychology; coaching>recreation; coal>carbon; coal>carbon dioxide; coal>carbon monoxide; coal>climate change; coal>funeral; coal>global warming; coal>iron; coal>oxygen; coal>pressure; coal>steam; coal>steel; coal>world; coal>animal; coal>bay; coal>beach; coal>canal; coal>circle; coal>cliff; coal>climate change; coal>coral; coal>dolphin; coal>erosion; coal>fishing; coal>flood; coal>house; coal>infrastructure; coal>insect; coal>island; coal>lake; coal>navy; coal>ocean; coal>plant; coal>pond; coal>port; coal>river; coal>salt; coal>sea; coal>shore; coal>solution; coal>surfing; coal>tide; coal>transport; coal>wave; coal>weather; coastline>coast; coat>paint; coat>skin; coconut>butterfly; coconut>carpet; coconut>flower; coconut>fruit; coconut>ghost; coconut>plant; coconut>seed; coconut>soap; coconut>theatre; coconut>witch; cod>beard; cod>crab; cod>export; cod>food; cod>heart; cod>species; cod>worm; code>biology; code>bit; code>chess; code>communication; code>computer; code>data; code>dna; code>gesture; code>information; code>journalism; code>language; code>length; code>marketing; code>music; code>phrase; code>sign; code>word; coffee>climate change; coffee>corn; coffee>illness; coffee>liver; coffee>milk; coffee>rice; coffee>shade; coffee>sugar; coffee>tea; coffee>turkey; coffee>wine; coffee>worm; coin>copper; coin>currency; coin>deer; coin>dice; coin>euro; coin>exchange rate; coin>gold; coin>inflation; coin>money; coin>penny; coin>silver; coincidence>earth; coincidence>genius; coincidence>paradox; coincidence>probability; coincidence>science; coincidence>statistics; coincidence>sun; cola>lemon; cola>pharmacist; cola>soft drink; cold>air; cold>atmosphere; cold>earth; cold>energy; cold>freezer; cold>frost; cold>hail; cold>heat; cold>ice; cold>ice cream; cold>iceberg; cold>mammal; cold>physics; cold>radiation; cold>snow; cold>sun; cold>temperature; cold>winter; coldness>cold; collaboration>ballet; collaboration>blog; collaboration>business; collaboration>community; collaboration>computer; collaboration>cooperation; collaboration>industry; collaboration>leadership; collaboration>medicine; collaboration>organization; collaboration>partnership; collaboration>piano; collaboration>socialism; collaboration>trade; collaboration>violin; collar>arrest; collar>slave; college>law; college>secondary school; college>university; collocation>vocation; collocation>cliché; collocation>grammar; collocation>idiom; collocation>phrasal verb; column>arch; column>architecture; column>relief; comb>hair; comb>metaphor; comb>perfume; comb>police; comb>tool; combat>assault; combat>kick; combat>knife; combat>law; combat>sword; combat>synonym; combat>war; combat>weapon; combat>violence; combination>probability; comeback>politics; comedian>comedy; comedian>humour; comedian>joke; comedian>laughter; comedy>clown; comedy>evil; comedy>film; comedy>humour; comedy>irony; comedy>laughter; comedy>literature; comedy>television; comedy>theatre; comedy>tragedy; comedy>word; comfort>health care; comfort>memory; comfort>pain; comfort>pleasure; comfort>suffering; comma>apostrophe; comma>clause; comma>full stop; comma>grammar; comma>punctuation; comma>semicolon; commander>army; commander>inspector; commerce>advertising; commerce>agriculture; commerce>business; commerce>capitalism; commerce>cargo; commerce>coin; commerce>communication; commerce>corporation; commerce>currency; commerce>economics; commerce>export; commerce>fair; commerce>finance; commerce>globalization; commerce>gold; commerce>harvest; commerce>import; commerce>industry; commerce>manufacturing; commerce>market; commerce>marketing; commerce>money; commerce>trade; commercial>advertising; commercial>commerce; commercial>trade; commitment>brand; commitment>contract; commitment>promise; committee>research; committee>secretary; commodity>agriculture; commodity>brand; commodity>coal; commodity>coffee; commodity>copper; commodity>economics; commodity>gold; commodity>inflation; commodity>market; commodity>mining; commodity>price; commodity>rice; commodity>salt; commodity>silver; commodity>sugar; commodity>wheat; commodity>trade; common sense>artificial intelligence; common sense>idea; common sense>logic; common sense>philosopher; common sense>relevance; common sense>wisdom; communication>architecture; communication>bacteria; communication>clothing; communication>collaboration; communication>conversation; communication>cooperation; communication>dialect; communication>diary; communication>feedback; communication>gesture; communication>grammar; communication>human; communication>information; communication>jargon; communication>message; communication>name; communication>noise; communication>plant; communication>rhythm; communication>soil; communication>sound; communication>symbol; communication>system; communication>writing; community>archaeology; community>belief; community>biology; community>city; community>communication; community>competition; community>construction; community>content; community>culture; community>disability; community>ecology; community>economics; community>family; community>festival; community>home; community>human; community>individual; community>intensity; community>intention; community>life; community>nation; community>neighbourhood; community>office; community>politics; community>preference; community>risk; community>role; community>selfishness; community>suburb; community>town; community>village; companion>friendship; company>bank; company>corporation; company>desire; company>duty; company>firm; company>goal; company>law; company>partnership; company>person; company>policy; company>resource; company>skill; comparative>advertising; comparative>suburb; comparative>superlative; competences>skill; competition>adaptation; competition>award; competition>baseball; competition>basketball; competition>biology; competition>brand; competition>budget; competition>celebrity; competition>championship; competition>civilization; competition>consumer; competition>cooperation; competition>cost; competition>country; competition>cricket; competition>culture; competition>democracy; competition>diving; competition>ecology; competition>election; competition>evolution; competition>extinction; competition>fishing; competition>food; competition>football; competition>funding; competition>government; competition>gymnastics; competition>income; competition>investor; competition>law; competition>monopoly; competition>nationality; competition>nature; competition>philosopher; competition>politics; competition>pride; competition>psychologist; competition>psychology; competition>recreation; competition>self-esteem; competition>sunlight; competition>tax; competition>tennis; competition>war; competition>water; competition>wealth; competitor>competition; complaint>birthday; complaint>definition; complaint>lawyer; complex>building; complex>complexity; complex>biology; complex>dna; complex>fluid; complex>racism; complex>skin; complex>therapy; complexity>biology; complexity>dimension; complexity>economics; complexity>feedback; complexity>observation; complexity>probability; complexity>property; complexity>science; complexity>simplicity; complexity>simulation; complexity>stock market; complexity>system; complexity>technology; component>ingredient; component>system; composer>arrangement; composer>jazz; composer>music; composer>musician; composer>performance; composer>performer; composer>song; compromise>acceptance; compromise>argument; compromise>communication; compromise>constitution; compromise>demand; computer>artificial intelligence; computer>bit; computer>bunch; computer>calculator; computer>commodity; computer>electronics; computer>icon; computer>laptop; computer>microphone; computer>programmer; computer>spreadsheet; computer>washing machine; computer>webcam; computer>video game; computer>wire; concentration>chemistry; concentration>solution; concept>idea; concept>learning; concept>logic; concept>man; concept>memory; concept>philosophy; concept>psychology; concept>skill; conception>concept; concern>worry; concert>audience; concert>choir; concert>dancing; concert>house; concert>jazz; concert>music; concert>musician; concert>nightclub; concert>orchestra; concert>performance; concert>rehearsal; concert>singer; concert>stadium; conclusion>result; concrete>arc; concrete>boat; concrete>carbon dioxide; concrete>chemistry; concrete>construction; concrete>fence; concrete>parking; concrete>sand; concrete>sugar; concrete>water; conference>meeting; confession>ritual; confession>sin; confidence>faith; confidence>police; confidence>security; confidence>self-confidence; confidence>shyness; confidence>synonym; confirmation>faith; confirmation>prayer; confirmation>priest; confirmation>saint; conscience>abortion; conscience>advertising; conscience>aggression; conscience>animal; conscience>artificial intelligence; conscience>authority; conscience>bird; conscience>brain; conscience>carbon footprint; conscience>chess; conscience>climate change; conscience>consciousness; conscience>consumer; conscience>contempt; conscience>culture; conscience>democracy; conscience>dignity; conscience>earth; conscience>ecology; conscience>evil; conscience>famine; conscience>fear; conscience>generosity; conscience>genetics; conscience>god; conscience>human rights; conscience>integrity; conscience>intellect; conscience>intelligence; conscience>justice; conscience>legislation; conscience>materialism; conscience>matter; conscience>mind; conscience>murder; conscience>parliament; conscience>philosophy; conscience>physics; conscience>politics; conscience>pride; conscience>propaganda; conscience>psychology; conscience>racism; conscience>reason; conscience>religion; conscience>remorse; conscience>self-awareness; conscience>shame; conscience>sin; conscience>society; conscience>sustainability; conscience>torture; conscience>truth; conscience>war; conscience>violence; consciousness>adaptation; consciousness>artificial intelligence; consciousness>awareness; consciousness>computer; consciousness>conscience; consciousness>dream; consciousness>experience; consciousness>explanation; consciousness>feeling; consciousness>information; consciousness>knowledge; consciousness>language; consciousness>medicine; consciousness>memory; consciousness>mind; consciousness>perception; consciousness>philosophy; consciousness>psychology; consciousness>robot; consciousness>self-awareness; consciousness>self; consciousness>sleep; consciousness>stroke; consciousness>validity; consent>crime; consent>excuse; consent>rape; consent>signature; consequence>punishment; conservation>sustainability; consideration>contract; consideration>legislation; consonant>alphabet; consonant>syllable; consonant>symbol; consonant>vowel; constitution>democracy; constitution>human rights; constitution>institution; constitution>liberty; constitution>parliament; constitution>precedent; constitution>president; constitution>prime minister; constitution>referendum; constitution>revolution; constitution>treaty; construction>accountant; construction>architect; construction>architecture; construction>budget; construction>building; construction>career; construction>consultant; construction>contract; construction>craft; construction>drawing; construction>electrician; construction>engineer; construction>fraud; construction>infrastructure; construction>planning; construction>plumber; construction>profession; construction>project; construction>supervisor; construction>vocation; consultant>engineering; consultant>finance; consultant>law; consultants>management; consultants>marketing; consultant>professional; consultant>surgery; consumer>business; consumer>commodity; consumer>household; consumer>individuality; consumer>marketing; consumption>consumer; container>bottle; container>box; container>jar; container>pottery; contempt>anger; contempt>disgust; contempt>prostitute; contempt>resentment; contents>content; contest>competition; contestant>celebrity; contestant>competition; contestant>professional; contestant>television; continent>earth; continent>geology; continent>island; continent>ocean; continent>volcano; contract>commerce; contract>consideration; contract>court; contract>country; contract>employment; contract>fraud; contract>legislation; contract>negotiation; contract>pact; contract>patient; contract>promise; contract>theatre; contradiction>belief; contradiction>capitalism; contradiction>irony; contradiction>paradox; contradiction>proposition; contradiction>socialism; contradiction>system; contradiction>truth; contribution>donation; contribution>payment; contribution>publication; control>self-control; controversy>argument; controversy>celebrity; controversy>climate change; controversy>crime; controversy>culture; controversy>economics; controversy>education; controversy>finance; controversy>gender; controversy>global warming; controversy>history; controversy>information; controversy>opinion; controversy>organization; controversy>philosophy; controversy>politics; controversy>religion; controversy>science; controversy>science fiction; controversy>sex; controversy>society; convenience>consumer; convenience>electricity; convenience>energy; convenience>frustration; convenience>money; convenience>petrol; convenience>technology; convenience>time; convention>treaty; conversation>communication; conversation>criticism; conversation>dialogue; conversation>gossip; conversation>humour; conversion>exchange rate; conviction>appeal; conviction>crime; conviction>law; conviction>punishment; conviction>verdict; cooks>cooking; cookie>biscuit; cookie>bun; cookie>butter; cookie>cake; cookie>carbon dioxide; cookie>chocolate; cookie>fat; cookie>flour; cookie>fruit; cookie>jam; cookie>milk; cookie>pastry; cookie>sandwich; cookie>spice; cookie>sugar; cooking>bacon; cooking>bakery; cooking>barbecue; cooking>berry; cooking>broccoli; cooking>carbon; cooking>cereal; cooking>corn; cooking>food; cooking>frying pan; cooking>meal; cooking>muscle; cooking>nutrition; cooking>olive; cooking>pottery; cooking>protein; cooking>recipe; cooking>sauce; cooking>seed; cooking>spice; cooking>spinach; cooking>wine; cooperation>collaboration; cooperation>emotion; cooperation>language; cooperation>teamwork; copper>aluminium; copper>brass; copper>bronze; copper>carbon monoxide; copper>dna; copper>dollar; copper>electronics; copper>glass; copper>gold; copper>mining; copper>silver; copper>telecommunications; copper>tin; copper>toilet; coral>animal; coral>canal; coral>carbon dioxide; coral>fish; coral>geology; coral>ocean; coral>pollution; coral>species; coral>tide; core>seed; corporation>business; corporation>company; corporation>contract; corporation>crime; corporation>employment; corporation>fraud; corporation>human rights; corporation>partnership; corporation>spice; correction>punishment; corridor>hall; corruption>blackmail; corruption>bribe; corruption>bribery; corruption>budget; corruption>discretion; corruption>fraud; corruption>liability; corruption>organization; corruption>philosophy; corruption>theft; cost>advertising; cost>business; cost>economics; cost>expense; cost>manufacturing; cost>money; cost>paradigm; cost>personnel; cost>price; cost>research; cost>retail; costume>beard; costume>clothing; costume>exile; costume>performance; costume>picture; costume>poem; costume>statue; costume>theatre; cottage>acre; cottage>fishing; cottage>mining; cottage>sailing; cotton>bacteria;

cotton>denim; cotton>export; cotton>frost; cotton>import; cotton>jeans; cotton>protein; cotton>soil; cotton>subsidy; cotton>tent; cotton>t-shirt; cotton>underwear; cotton>water;
cotton>wool; cough>bacteria; cough>insomnia; cough>lung; cough>smoking; cough>virus; council>city; council>committee; council>county; council>government; council>town;
count>article; count>language; count>pair; count>palace; counter>electronics; counter>ratio; country>count; country>indefinite article; country>nation; country>synonym;
country>burial; country>city; country>count; country>country; country>hospital; country>magistrate; country>province; country>region; country>tax; country>town; country>village;
courage>fear; courage>hero; courage>lion; courage>love; courage>pain; courage>psychology; courage>religion; courage>risk; courage>scandal; courage>shame;
courage>uncertainty; courage>virtue; course>main course; court>appeal; court>authority; court>constitution; court>government; court>institution; court>judge; court>law;
court>lawyer; court>trial; courtesy>conversation; courtesy>elegance; courtesy>intellectual; courtesy>kindness; courtesy>politeness; cousin>family; cousin>generation;
cousins>grandparent; cousins>parent; cousins>sibling; cow>cattle; coverage>insurance; coverage>news; crab>animal; crab>bacteria; crab>predator; crab>shore; crab>species;
crab>tail; crab>tide; crab>worm; crackdown>car; crackdown>police; crackdown>video game; craft>agriculture; craft>customer; craft>education; craft>fair; craft>glass;
craft>industry; craft>material; craft>metal; craft>paper; craft>profession; craft>professional; craft>relief; craft>science; craft>skill; craft>trade; craft>tradition; craft>vocation;
craft>wood; craft>workshop; crash>linen; crash>sleep; cream>air; cream>bacteria; cream>butter; cream>cattle; cream>cheese; cream>coffee; cream>honey; cream>ice cream;
cream>milk; cream>paint; cream>soap; cream>wine; creation>art; creation>invention; creativity>analogy; creativity>architecture; creativity>art; creativity>artificial
intelligence; creativity>collaboration; creativity>design; creativity>economics; creativity>economist; creativity>education; creativity>engineering; creativity>evolution;
creativity>existence; creativity>fair; creativity>genius; creativity>greatness; creativity>imagination; creativity>innovation; creativity>insight; creativity>intelligence; creativity>invention;
creativity>language; creativity>literature; creativity>metaphor; creativity>music; creativity>philosophy; creativity>psychology; creativity>resource; creativity>revelation;
creativity>science; creativity>supervisor; creativity>technology; creativity>theory; creativity>threat; creativity>wealth; creature>life; credibility>integrity; credibility>witness; credit
card>cash; credit card>cheque; credit card>college; credit card>consumer; credit card>debit card; credit card>debt; credit card>electronics; credit card>expense; credit card>forgery;
credit card>fuel; credit card>interest; credit card>metal; credit card>payment; credit card>receipt; credit card>signature; credit card>tax; credit card>tuition; credit>credibility;
crew>airline; crew>hierarchy; crew>sport; crew>team; cricket>baseball; cricket>hockey; cricket>law; crime>abortion; crime>alcohol; crime>arrest; crime>assault; crime>civilization;
crime>commerce; crime>consensus; crime>country; crime>creativity; crime>crime; crime>crime; crime>definition; crime>economics; crime>employer; crime>employment;
crime>family; crime>fear; crime>gambling; crime>government; crime>imprisonment; crime>justice; crime>king; crime>law; crime>liberty; crime>logic; crime>murder; crime>paradox;
crime>payment; crime>police; crime>politics; crime>population; crime>psychology; crime>punishment; crime>rape; crime>reason; crime>religion; crime>revenge; crime>robbery;
crime>sin; crime>slavery; crime>society; crime>statistics; crime>theft; crime>treaty; crime>trial; crime>war; criminal>crime; crisis>affair; crisis>combat; crisis>disaster;
crisis>earthquake; crisis>hazard; crisis>health; crisis>homelessness; crisis>probability; crisis>recession; crisis>revolution; crisis>security; crisis>self-esteem; crisis>spies;
crisis>threat; crisis>war; critic>analysis; critic>review; criticism>ambiguity; criticism>authority; criticism>complaint; criticism>controversy; criticism>criminal;
criticism>critic; criticism>denial; criticism>hypocrisy; criticism>noun; criticism>prejudice; criticism>protest; criticism>self-esteem; criticism>terrorist; criticism>verb;
crocodile>aggression; crocodile>bite; crocodile>bird; crocodile>carbon dioxide; crocodile>cold; crocodile>deer; crocodile>dinosaur; crocodile>ecology;
crocodile>evolution; crocodile>extinction; crocodile>fish; crocodile>foot; crocodile>handbag; crocodile>heart; crocodile>helicopter; crocodile>hierarchy; crocodile>lake;
crocodile>mammal; crocodile>measurement; crocodile>muscle; crocodile>nest; crocodile>nostril; crocodile>predator; crocodile>reproduction; crocodile>reptile; crocodile>river;
crocodile>shark; crocodile>skull; crocodile>species; crocodile>tongue; crop>agriculture; crop>animal; crop>bacteria; crop>clothing; crop>cotton; crop>farming; crop>food;
crop>harvest; crop>human; crop>milk; crop>mushroom; crop>pet; crop>plant; crop>potato; crop>rice; crop>species; crop>wheat; crop>virus; crop>yogurt; cross>addition;
cross>anchor; cross>era; cross>firefighter; cross>fork; cross>life; cross>world; crowds>bird; crowds>shopping; cruelty>divorce; cruelty>law; cruelty>pleasure; cruelty>punishment;
cruelty>suffering; cruelty>torture; cruelty>violence; crystal>atom; crystal>diamond; crystal>glass; crystal>liquid; crystal>metal; crystal>salt; crystal>snow;
crystal>temperature; cucumber>agriculture; cucumber>bean; cucumber>plant; cucumber>spice; cucumber>turkey; cucumber>vegetable; cucumber>vinegar; cultivation>spirit;
culture>agriculture; culture>archaeology; culture>architecture; culture>art; culture>capitalism; culture>child; culture>civilization; culture>commerce; culture>communication;
culture>cow; culture>dialect; culture>education; culture>elite; culture>evolution; culture>experience; culture>fashion; culture>festival; culture>film; culture>gender;
culture>globalization; culture>history; culture>holiday; culture>human; culture>language; culture>literature; culture>mother; culture>music; culture>myth; culture>nationality;
culture>perfection; culture>philosophy; culture>photography; culture>psychology; culture>religion; culture>ritual; culture>society; culture>statistics; culture>symbol;
culture>technology; culture>tool; culture>tradition; cup>trophy; cupboard>central heating; cupboard>dirty; cupboard>dust; cupboard>food; cupboard>linen; cupboard>towel;
cupboard>wood; cure>cancer; cure>disease; cure>medication; cure>surgery; cure>symptom; cure>therapy; curiosity>animal; curiosity>attention; curiosity>cat; curiosity>death;
curiosity>emotion; curiosity>exploration; curiosity>happiness; curiosity>human; curiosity>infancy; curiosity>instinct; curiosity>learning; curiosity>memory; curiosity>motivation;
curiosity>violence; currency>bank; currency>banking; currency>cash; currency>cheque; currency>coin; currency>copper; currency>debt; currency>dollar; currency>euro;
currency>exchange rate; currency>inflation; currency>loan; currency>money; currency>monopoly; currency>receipt; currency>stock; currency>treaty; curriculum>adult;
curriculum>child; curriculum>college; curriculum>education; curriculum>education; curriculum>idea; curriculum>knowledge; curriculum>lesson; curriculum>reality; curriculum>school;
curriculum>society; curriculum>syllabus; curriculum>teaching; curriculum>university; currys>apple; currys>banana; currys>beef; currys>bread; currys>butter; currys>carrot; currys>coconut;
currys>cream; currys>dinner; currys>garlic; currys>herb; currys>honey; currys>lunch; currys>onion; currys>pork; currys>potato; currys>rice; currys>spice; currys>tuna; currys>vegetable;
currys>vegetarian; currys>wheat; currys>wine; currys>yogurt; curtain>button; curtain>cloth; curtain>department store; curtain>door; curtain>fabric; curtain>knot; curtain>light;
curtain>night; curtain>retail; curtain>rope; curtain>rubber; curtain>sleep; curtain>theatre; curtain>water; curtain>>window; curve>astronomy; cushion>carpet; cushion>chair;
cushion>fashion; cushion>leather; cushion>furniture; cushion>grass; cushion>leather; cushion>palace; cushion>paper; cushion>pillow; cushion>soil; cushion>wool;
custom>customs; custom>tradition; customer>consumer; customer>employee; customer>marketing; customer>seller; customs>authority; customs>export; customs>hazard;
customs>port; customs>tax; cut>wound; cutlery>camping; cutlery>fast food; cutlery>food; cutlery>fork; cutlery>knife; cutlery>plastic; cutlery>razor; cutlery>spoon; cutlery>steel;
cutlery>sword; cutlery>tool; cv>syllable; cycle>bicycle; cycling>bicycle; cycling>carbon dioxide; cycling>city; cycling>mail; cycling>obesity; cycling>recreation; cycling>sport;
cycling>transport; cyclist>cycling; dad>father; damage>injury; dance>animal; dance>audience; dance>ballet; dance>civilization; dance>culture; dance>disc;
dance>entertainment; dance>exercise; dance>gesture; dance>gymnastics; dance>hip-hop; dance>history; dance>individuality; dance>knowledge; dance>music; dance>narrative;
dance>performance; dance>professional; dance>rainforest; dance>rhythm; dance>ritual; dance>scholar; dance>society; dance>symbol; dance>vocabulary; dancer>dance;
dancing>dance; danger>risk; darkness>black; darkness>energy; darkness>shadow; dash>dialogue; dash>information; dash>full stop; dash>hyphen; dash>prefix; dash>punctuation;
data>alphabet; data>computer; data>database; data>engineering; data>geography; data>image; data>information; data>inflation; data>measurement; data>number; data>sign;
data>statistics; database>acid; database>availability; database>data; database>economy; database>email; database>knowledge; database>library; database>market;
database>raid; database>security; database>spreadsheet; daughter>female; daughter>girl; daughter>offspring; daughter>parent; daughter>son; daughter>woman; dawn>horizon;
dawn>morning; dawn>noon; dawn>pie; dawn>sky; dawn>sun; dawn>sunrise; dawn>sunset; day>astronomy; day>atom; day>calendar; day>daylight; day>deer; day>evening;
day>holiday; day>horizon; day>hour; day>midnight; day>morning; day>night; day>noon; day>public transport; day>rabbit; day>season; day>second; day>star; day>sun;
day>sunlight; day>sunrise; day>sunset; day>tide; day>time; day>water; day>week; day>year; daylight>earth; daylight>energy; daylight>moonlight; daylight>noon; daylight>pain;
daylight>sun; daylight>sunlight; daylight>sunrise; daylight>sunset; daylight>window; death>contract; death>accident; death>adaptation; death>animal; death>breath; death>burial;
death>cancer; death>coal; death>consciousness; death>disease; death>evolution; death>examination; death>exercise; death>extinction; death>funeral; death>gene; death>heart;
death>human; death>inheritance; death>injury; death>life; death>longevity; death>medicine; death>murder; death>nerve; death>obesity; death>oxygen; death>philosophy;
death>predator; death>scenario; death>science fiction; death>skeleton; death>stroke; death>suicide; death>time; death>tobacco; death>argument;
debate>audience; debate>controversy; debate>conversation; debate>election; debate>entertainment; debate>judge; debate>law; debate>majority; debate>parliament;
debate>president; debate>prime minister; debate>proposition; debate>team; debate>vote; debit card>bank account; debit card>cash; debit card>cheque; debit card>credit card;
debit card>euro; debit card>logo; debit card>plastic; debit card>retailer; debit card>signature; debit card>travel agent; debt>asset; debt>banking; debt>company; debt>corporation;
debt>credit card; debt>currency; debt>economist; debt>finance; debt>government; debt>inflation; debt>interest; debt>invest; debt>loan; debt>metaphor; debt>money;
debt>payment; debt>property; debt>risk; debt>saving; debt>stock; debt>time; debt>year; decade>century; decade>millennium; decade>year; december>day; december>length;
december>month; december>year; deception>anger; deception>criticism; deception>embarrassment; deception>experiment; deception>forgery; deception>fraud; deception>ink;
deception>lie; deception>propaganda; deception>psychology; deception>reality; deception>self-esteem; deception>sound; deception>truth; decision>judgment; deck>bus;
deck>floor; deck>storey; deck>swimming pool; decline>culture; decoration>beauty; dedication>chapel; dedication>icon; dedication>temple; deer>adjective; deer>animal; deer>bull;
deer>cattle; deer>dna; deer>fruit; deer>leaf; deer>liver; deer>mammal; deer>predator; deer>salmon; deer>stomach; deer>turkey; defeat>failure; defeat>victory;
deficiency>construction; definition>phrase; definition>prime minister; definition>rectangle; definition>symbol; definition>triangle; definition>word; degree>comparative;
degree>superlative; delegation>leadership; delegation>management; delight>happiness; demand>glasses; demand>recession; democracy>consensus; democracy>constitution;
democracy>corporation; democracy>human rights; democracy>intelligence; democracy>law; democracy>organization; democracy>president; democracy>prime minister;
democracy>referendum; democracy>public; democracy>revolution; democracy>socialism; democracy>wealth; denial>attention; denial>bias; denial>death; denial>emotion;
denial>evidence; denial>harassment; denial>lie; denial>rape; denial>reality; denial>research; denial>truth; denim>boot; denim>cotton; denim>documentary; denim>dress;
denim>handbag; denim>hat; denim>jacket; denim>jeans; denim>shirt; denim>shoe; denim>shorts; density>air; density>aluminium; density>copper; density>diamond; density>earth;
density>gold; density>gram; density>ice; density>iron; density>kilogram; density>lead; density>liquid; density>pressure; density>silver; density>solution; density>sun;
density>temperature; density>tin; density>water; density>weight; density>volume; density>wood; dentist>antibiotic; dentist>mouth; deodorant>alcohol; deodorant>aluminium;
deodorant>bacteria; deodorant>dna; deodorant>inventor; deodorant>irritation; deodorant>perfume; department store>clock; department store>escalator; department
store>marketing; department store>redevelopment; department store>retail; department>department store; department>essay; department>government; department>university;
deprivation>liberty; deprivation>poverty; deprivation>starvation; descendant>ancestor; descendant>hierarchy; description> cliché; description>definition; description>fiction;
description>imagination; description>narrative; description>relevance; description>sentiment; desert>ant; desert>camel; desert>carbon dioxide; desert>cattle; desert>continent;
desert>copper; desert>drought; desert>earth; desert>explosive; desert>fly; desert>fog; desert>goat; desert>gold; desert>ice; desert>iron; desert>lake; desert>landscape;
desert>mammal; desert>rain; desert>region; desert>reptile; desert>salt; desert>science fiction; desert>sheep; desert>slave; desert>snake; desert>snow; desert>spider; desert>sun;
desert>sunlight; desert>temperature; desert>turkey; design>analysis; design>architect; design>architecture; design>construction; design>creativity; design>definition;
design>designer; design>document; design>emotion; design>engineering; design>evaluation; design>fashion; design>goal; design>implementation;
design>management; design>manufacturing; design>pottery; design>presentation; design>requirement; design>research; design>science; design>specification; design>thought;
designer>architect; designer>architecture; designer>clothing; designer>design; designer>document; designer>furniture; designer>painting; designer>profession;
designer>sculpture; desire>marketing; desk>book; desk>bookmark; desk>computer; desk>content; desk>furniture; desk>office; desk>pen; desk>steel; desk>wood; desk>writing;
desktop>desk; desperation>panic; dessert>biscuit; dessert>cake; dessert>cookie; dessert>fat; dessert>flour; dessert>fruit; dessert>honey; dessert>ice cream; dessert>jam;
dessert>pastry; dessert>pie; dessert>pudding; dessert>sugar; destination>travel; destiny>art; destiny>luck; destiny>philosophy; destiny>proposition; detail>complexity;
detective>burglary; detective>civilian; detective>credit card; detective>crime; detective>fiction; detective>fraud; detective>inspector; detective>police; detective>robbery;
determination>decision; determination>determiner; determination>measurement; determiner>adjective; determiner>grammar; determiner>noun; determiner>phrase;
determiner>reference; determiner>word; device>gadget; device>machine; device>tool; devil>angel; devil>beauty; devil>culture; devil>evil; devil>goat; devil>god; devil>hell;
devil>judge; devil>legend; devil>pig; devil>prosecutor; devil>religion; devil>sheep; devil>sin; devil>wisdom; devil>wisdom; devil>wisdom; devil>wisdom; devil>wisdom; devil>wisdom; devil>wisdom;
diagram>chart; diagram>engineering; diagram>grammar; diagram>graphics; diagram>illustration; diagram>information; diagram>map; diagram>synonym; dialect>elite;
dialect>jargon; dialect>language; dialect>slang; dialect>vocabulary; dialogue>conversation; dialogue>god; dialogue>language; dialogue>literature; dialogue>narrative;
dialogue>philosophy; diamond>carbon; diamond>carbon dioxide; diamond>crystal; diamond>earth; diamond>electronics; diamond>ice; diamond>icon; diamond>laser;
diamond>oxygen; diamond>toughness; diamond>>window; diamond>x-ray; diary>biography; diary>blog; diary>fiction; diary>witness; dice>board game; dice>density; dice>gambling;
dice>horse; dice>museum; dice>plastic; dice>plural; dice>singular; dice>sphere; dictionary>computer; dictionary>concept; dictionary>definition; dictionary>idiom;

dictionary>metaphor; difficulty>problem; digestion>acid; digestion>alcohol; digestion>animal; digestion>bacteria; digestion>beak; digestion>bird; digestion>blood; digestion>cat; digestion>cheese; digestion>cow; digestion>fat; digestion>food; digestion>liver; digestion>mammal; digestion>mouth; digestion>muscle; digestion>nerve; digestion>nutrition; digestion>pig; digestion>protein; digestion>silk; digestion>steel; digestion>stomach; digestion>sugar; digestion>tongue; digital camera>camera; digital camera>electronics; digital camera>mobile phone; digital camera>photograph; digital camera>photographer; digital camera>portrait; digital camera>video; dignity>abortion; dignity>angel; dignity>conscience; dignity>god; dignity>human rights; dignity>integrity; dignity>pride; dignity>privacy; dignity>reason; dignity>self-esteem; dignity>self-respect; dignity>video game; dilemma>idiom; dilemma>logic; dilemma>paradox; dilemma>problem; dining room>castle; dining room>kitchen; dining room>living room; dining room>staircase; dinner>breakfast; dinner>dessert; dinner>food; dinner>lunch; dinner>meal; dinner>noon; dinner>snack; dinner>sunday; dinner>supper; dinner>advertising; dinosaur>biology; dinosaur>bird; dinosaur>bone; dinosaur>cheek; dinosaur>chemistry; dinosaur>chicken; dinosaur>computer; dinosaur>crocodile; dinosaur>extinction; dinosaur>feather; dinosaur>fiction; dinosaur>geology; dinosaur>kidney; dinosaur>literature; dinosaur>mammal; dinosaur>nest; dinosaur>physics; dinosaur>protein; dinosaur>reptile; dinosaur>science; dinosaur>skeleton; dinosaur>snake; dinosaur>tooth; dinosaur>wrist; diploma>ambassador; diploma>delegate; diploma>diplomacy; diploma>diplomat; diploma>electronics; diploma>king; diploma>leather; diploma>university; diplomacy>ambassador; diplomacy>climate change; diplomacy>culture; diplomacy>diplomat; diplomacy>economics; diplomacy>human rights; diplomacy>negotiation; diplomacy>politician; diplomacy>propaganda; diplomacy>republic; diplomacy>sailing; diplomacy>strategy; diplomacy>trade; diplomacy>treaty; diplomacy>war; diplomat>ambassador; diplomat>culture; diplomat>diploma; diplomat>diplomacy; diplomat>economics; diplomat>hip; diplomat>law; diplomat>self-esteem; diplomat>university; directions>direction; dirt>clothes; dirt>commerce; dirt>disgust; dirt>dust; dirt>dustbin; dirt>immune system; dirt>pregnancy; dirt>restaurant; dirt>skin; dirt>soil; disability>blindness; disability>disease; disability>employment; disability>extreme sports; disability>pity; disability>safety; disability>sense; disability>software; disability>transportation; disability>wheelchair; disadvantage>extinction; disagreement>consensus; disagreement>controversy; disappointment>blame; disappointment>frustration; disappointment>grief; disappointment>happiness; disappointment>immune system; disappointment>lottery; disappointment>optimism; disappointment>probability; disappointment>risk; disappointment>stock market; disaster>accident; disaster>crisis; disaster>earthquake; disaster>emergency; disaster>explosion; disaster>fire; disaster>flood; disaster>hazard; disaster>risk; disc jockey>jazz; disc jockey>microphone; disc jockey>nightclub; disc jockey>stadium; disc-disc jockey; discipline>motivation; discipline>prison; discipline>punishment; discipline>self-control; discipline>training; discipline>virtue; disco>album; disco>arrangement; disco>baseball; disco>celebrity; disco>cello; disco>disc jockey; disco>dj; disco>flute; disco>hip-hop; disco>jazz; disco>medal; disco>music; disco>necklace; disco>nightclub; disco>orchestra; disco>piano; disco>racism; disco>soundtrack; disco>techno; disco>television; disco>trumpet; disco>violin; discomfort>comfort; discretion>appeal; discretion>judge; discretion>jury; discretion>noun; discretion>police; discretion>prosecutor; discrimination>employer; discrimination>gender; discrimination>institution; discrimination>nationality; discrimination>prejudice; discrimination>racism; discrimination>slavery; discrimination>stereotype; discussion>conversation; disease>addiction; disease>attention; disease>biology; disease>cancer; disease>cure; disease>death; disease>disability; disease>emotion; disease>exercise; disease>illness; disease>infection; disease>injury; disease>medication; disease>metaphor; disease>nutrition; disease>obesity; disease>outbreak; disease>pain; disease>poverty; disease>pregnancy; disease>slavery; disease>stroke; disease>surgery; disease>symptom; disease>vaccination; disease>vaccination; disguise>celebrity; disguise>costume; disguise>mask; disguise>science fiction; disgust>anger; disgust>consciousness; disgust>consent; disgust>contempt; disgust>disease; disgust>emotion; disgust>fear; disgust>god; disgust>milk; disgust>personality; disgust>privacy; disgust>racism; disgust>rat; disgust>sadness; disgust>sex; disgust>shame; dishonesty>consent; dishonesty>court; dishonesty>fraud; dishonesty>jury; dishonesty>robbery; dishonesty>theft; dishwasher>cutlery; dishwasher>perfume; dishwasher>restaurant; dishwasher>salt; dishwasher>temperature; dishwasher>washing machine; disk-disc; dislike>disgust; disorder>disease; disposition>belief; disposition>mind; disposition>truth; dispute>controversy; disrespect>respect; disruption>adoption; dissertation>thesis; distance>formula; distance>length; distance>leisure; distance>physics; distance>ruler; distance>statistics; distinction>award; distraction>attention; distraction>prayer; distress>suffering; district>authority; district>county; district>leisure; district>recycling; district>region; district>tax; dive>diving; divers>diving; diving>dance; diving>gymnastics; diving>sport; diving>swimming pool; divorce>addiction; divorce>god; divorce>lawyer; divorce>magistrate; divorce>marriage; divorce>workaholic; divorce>vow; dj-disc jockey; dna>agriculture; dna>animal; dna>atom; dna>bacteria; dna>biology; dna>blood; dna>brain; dna>cancer; dna>carbon; dna>earth; dna>evolution; dna>gene; dna>genetics; dna>hair; dna>life; dna>plant; dna>skin; dna>species; dna>temperature; dna>virus; dna>x-ray; doctor>surgeon; document>author; document>book; document>contract; document>evidence; document>information; document>ink; document>journal; document>laptop; document>material; document>paper; document>privacy; document>radio; document>report; document>sign; document>television; document>thesis; dog>animal; dog>blindness; dog>cat; dog>chocolate; dog>fox; dog>garlic; dog>grape; dog>horse; dog>human; dog>hunting; dog>leopard; dog>mammal; dog>pet; dog>pregnancy; dog>puppy; dog>restaurant; dog>tail; dog>tick; dog>tiger; dog>wolf; doll>archaeology; doll>art; doll>bone; doll>cereal; doll>cloth; doll>clothing; doll>fashion; doll>fur; doll>furniture; doll>leather; doll>plastic; doll>psychologist; doll>rubber; doll>slave; doll>toy; doll>transportation; doll>wood; dollar>currency; dollar>euro; dolphin>culture; dolphin>disease; dolphin>eyesight; dolphin>fish; dolphin>garlic; dolphin>infection; dolphin>navy; dolphin>research; dolphin>shark; dolphin>skeleton; dolphin>taste; dolphin>tuna; dolphin>whale; donation>blood; donation>cash; donation>clothing; donation>consideration; donation>food; donation>gift; donation>toy; donkey>animal; donkey>cartoon; donkey>desert; donkey>mammal; donkey>proverb; donkey>sheep; donkey>straw; donkey>synonym; donkey>zebra; donor>donation; doom>destiny; doors>conditioning; doors>alarm; doors>animal; doors>atmosphere; doors>ceiling; doors>chest; doors>climate; doors>convenience; doors>curtain; doors>disguise; doors>fire; doors>floor; doors>garden; doors>gate; doors>glass; doors>horse; doors>id card; doors>knee; doors>ladder; doors>light; doors>literature; doors>metaphor; doors>noise; doors>people; doors>pressure; doors>prison; doors>privacy; doors>remote control; doors>ritual; doors>rubber; doors>safety; doors>security; doors>switch; doors>symbol; doors>ton; doors>wardrobe; doorway>door; dose>quantity; dot>full stop; doubt>authority; doubt>belief; doubt>childhood; doubt>deception; doubt>emotion; doubt>fact; doubt>future; doubt>history; doubt>law; doubt>logic; doubt>mind; doubt>paradox; doubt>politics; doubt>probability; doubt>question; doubt>reality; doubt>reason; doubt>religion; doubt>tradition; doubt>uncertainty; download>email; drafts>drought; drama>actor; drama>audience; drama>collaboration; drama>dance; drama>dialogue; drama>entertainment; drama>episode; drama>fiction; drama>film; drama>grammar; drama>institution; drama>literature; drama>music; drama>opera; drama>performance; drama>poetry; drama>ritual; drama>soap opera; drama>song; drama>television; drama>theatre; drama>tragedy; drama>wit; draught>draft; drawback>commerce; drawback>export; drawback>law; drawback>sugar; drawback>warehouse; drawer>drawing; drawing>blackboard; drawing>brush; drawing>diagram; drawing>illustration; drawing>ink; drawing>leather; drawing>paper; drawing>pen; drawing>pencil; drawing>ruler; drawing>shade; drawing>silver; drawing>anger; dream>anxiety; dream>creativity; dream>devil; dream>earth; dream>evil; dream>fantasy; dream>fear; dream>happiness; dream>heaven; dream>idea; dream>illness; dream>image; dream>mind; dream>nightmare; dream>novelist; dream>perception; dream>prediction; dream>sadness; dream>scientist; dream>sleep; dream>taste; dress>bride; dress>clothing; dress>fashion; dress>girl; dress>skirt; dress>tennis; dress>thigh; dress>trousers; dress>wedding; dress>woman; drink>alcohol; drink>beer; drink>cancer; drink>carrot; drink>chicken; drink>coffee; drink>cucumber; drink>culture; drink>food; drink>fruit; drink>human; drink>juice; drink>lemonade; drink>liquid; drink>milk; drink>pub; drink>soft drink; drink>soup; drink>spoon; drink>tea; drink>water; drink>wine; drink>yogurt; drive>motivation; drive>road; drop>chest; drop>waist; drought>agriculture; drought>average; drought>climate change; drought>desert; drought>disaster; drought>economy; drought>erosion; drought>famine; drought>habitat; drought>human; drought>hunger; drought>industry; drought>lake; drought>landscape; drought>rainforest; drought>refugee; drought>ship; drought>snake; drought>soil; drought>unrest; drought>war; drought>wit; drug>animal; drug>beer; drug>body; drug>chemical; drug>cigarette; drug>coffee; drug>consciousness; drug>cream; drug>culture; drug>food; drug>government; drug>human; drug>illness; drug>law; drug>matter; drug>medicine; drug>mind; drug>mouth; drug>perception; drug>pharmacist; drug>pharmacy; drug>tobacco; drug>wine; drum>jazz; drum>sound; duck>animal; duck>baseball; duck>beak; duck>bird; duck>fox; duck>swan; dump>waste; duration>time; dust>carpet; dust>climate change; dust>desert; dust>engineering; dust>fur; dust>hair; dust>laptop; dust>manufacturing; dust>material; dust>paper; dust>repair; dust>road; dust>surface; duty>debt; duty>employment; duty>obligation; duty>sacrifice; duty>soldier; duty>tradition; duvet>blanket; duvet>cotton; duvet>feather; duvet>pillow; duvet>silk; duvet>wool; dvd>cd; dvd>movie; dvd>pencil; eagerness>enthusiasm; eagle>beak; eagle>bird; eagle>extinction; eagle>religion; eagle>snake; eagle>sun; ear>bat; ear>cancer; ear>earring; ear>head; ear>muscle; ear>sense; ear>sound; earnings>commodity; earnings>corporation; earnings>income; earnings>investment; earnings>tax; earring>bacteria; earring>bone; earring>ear; earring>friction; earring>glass; earring>infection; earring>jewellery; earring>metal; earring>plastic; earring>sailor; earring>wood; earth>aluminium; earth>atmosphere; earth>carbon dioxide; earth>chemical; earth>climate; earth>culture; earth>density; earth>desert; earth>dinosaur; earth>earthquake; earth>evolution; earth>geography; earth>geology; earth>global warming; earth>human; earth>iron; earth>life; earth>lightning; earth>mammal; earth>metre; earth>oxygen; earth>ozone; earth>planet; earth>pollution; earth>satellite; earth>season; earth>species; earth>sun; earth>sunlight; earth>tide; earth>tornado; earth>volcano; earth>world; earthquake>building; earthquake>density; earthquake>disease; earthquake>earth; earthquake>fire; earthquake>liquid; earthquake>turkey; earthquake>volcano; east>adjective; east>adverb; east>earth; east>geography; east>map; east>north; east>noun; east>south; east>sun; east>west; echo>telephone; ecology>adaptation; ecology>agriculture; ecology>ant; ecology>bacteria; ecology>bee; ecology>biology; ecology>carbon; ecology>carbon dioxide; ecology>climate; ecology>consumer; ecology>coral; ecology>dolphin; ecology>energy; ecology>erosion; ecology>evolution; ecology>extinction; ecology>flower; ecology>gene; ecology>genetics; ecology>global warming; ecology>immigration; ecology>landscape; ecology>leaf; ecology>materialism; ecology>ocean; ecology>oxygen; ecology>pond; ecology>population; ecology>predator; ecology>science; ecology>species; ecology>temperature; ecology>wasp; ecology>whale; economics>banking; economics>budget; economics>capitalism; economics>choice; economics>communication; economics>corporation; economics>economy; economics>exchange rate; economics>experiment; economics>finance; economics>globalization; economics>historian; economics>inflation; economics>insurance; economics>leisure; economics>management; economics>market; economics>money; economics>monopoly; economics>nature; economics>paradigm; economics>policy; economics>politics; economics>pollution; economics>poverty; economics>price; economics>recession; economics>scarcity; economics>science; economics>slavery; economics>slope; economics>socialist; economics>statistics; economics>sustainability; economics>technology; economics>trade; economics>uncertainty; economics>unemployment; economics>wealth; economist>bank; economist>business; economist>college; economist>commerce; economist>communication; economist>economics; economist>finance; economist>globalization; economist>government; economist>history; economist>law; economist>management; economist>market; economist>marketing; economist>philosophy; economist>politics; economist>politician; economist>politics; economist>statistics; economist>theory; economist>university; economy>agriculture; economy>bank; economy>banking; economy>capitalism; economy>coal; economy>commerce; economy>company; economy>competition; economy>corn; economy>currency; economy>debt; economy>debt; economy>demand; economy>economics; economy>economist; economy>engineering; economy>exchange rate; economy>film; economy>finance; economy>geography; economy>globalization; economy>history; economy>inflation; economy>infrastructure; economy>investment; economy>iron; economy>management; economy>manufacturing; economy>mining; economy>profession; economy>research; economy>scarcity; economy>stock market; economy>technology; economy>trade; economy>transport; economy>unemployment; economy>wood; economy>world; edge>blade; edition>paper; education>adult; education>agriculture; education>architecture; education>biology; education>child; education>college; education>curriculum; education>diploma; education>engineering; education>experience; education>history; education>knowledge; education>learning; education>literacy; education>medicine; education>organization; education>philosopher; education>philosophy; education>politics; education>profession; education>professor; education>psychology; education>school; education>science; education>secondary school; education>student; education>syllabus; education>teacher; education>telephone; education>training; education>university; education>violin; education>writing; effect>result; effectiveness>efficiency; effectiveness>management; effectiveness>medicine; effectiveness>physics; efficiency>effectiveness; effort>energy; election>business; election>corporation; election>propaganda; election>referendum; election>statistics; electrician>electronics; electrician>hammer; electricity>air conditioning; electricity>atom; electricity>earth; electricity>electronics; electricity>force; electricity>friction; electricity>headache; electricity>height; electricity>lighting; electricity>lightning; electricity>matter; electricity>muscle; electricity>shark; electricity>steam; electricity>sugar; electricity>switch; electricity>torture; electricity>touch; electricity>wave; electronics>computer; electronics>counter; electronics>electricity; electronics>engineering; electronics>heat; electronics>radiation; electronics>radio; electronics>spice; electronics>switch; electronics>system; electronics>telecommunications; electronics>wire; elegance>beauty; elegance>chemistry; elegance>design; elegance>effectiveness; elegance>engineering; elegance>essence; elegance>elegance>pharmacy; elegance>simplicity; elegance>synonym; element>weather; elephant>animal; elephant>camel; elephant>circus; elephant>desert; elephant>dna; elephant>dolphin; elephant>emotion; elephant>empathy; elephant>erosion; elephant>giraffe; elephant>lion; elephant>self-awareness; elephant>skull; elephant>tiger; elephant>zoo; elite>capitalism; elite>tax; email>bracket; email>corporation; email>laptop; email>message board; email>mobile phone; email>spelling; embarrassment>anger; embarrassment>anxiety; embarrassment>birthday; embarrassment>criticism; embarrassment>denial; embarrassment>dignity; embarrassment>emotion; embarrassment>environment; embarrassment>gossip; embarrassment>knowledge; embarrassment>privacy; embarrassment>shame; embarrassment>skill; embrace>acceptance; embrace>hug; emergency>accident; emergency>ambulance; emergency>donation; emergency>electricity; emergency>fire; emergency>firefighter; emergency>flood; emergency>gas; emergency>government; emergency>hazard; emergency>health; emergency>human; emergency>life;

emergency-likelihood; emergency-management; emergency-observation; emergency-police; emergency-principle; emergency-probability; emergency-professional; emergency-property; emergency-rescue; emergency-risk; emergency-stroke; emergency-tax; emergency-tornado; emergency-training; emission-noise; emotion-aggression; emotion-anger; emotion-artificial intelligence; emotion-contempt; emotion-curiosity; emotion-disgust; emotion-disposition; emotion-economics; emotion-education; emotion-evolution; emotion-fear; emotion-feeling; emotion-happiness; emotion-history; emotion-hunger; emotion-irritation; emotion-law; emotion-literature; emotion-love; emotion-mammal; emotion-marriage; emotion-medicine; emotion-motivation; emotion-philosophy; emotion-psychology; emotion-reason; emotion-reptile; emotion-sadness; emotion-virtue; empathy-crowd; empathy-dolphin; empathy-emotion; empathy-fantasy; empathy-pity; empathy-science fiction; empathy-sympathy; empathy-toddler; emperor-coup; emperor-empire; emperor-flag; emperor-prime minister; emperor-prince; emperor-religion; emperor-republic; empire-commerce; empire-election; empire-emperor; empire-euro; empire-realm; empire-republic; empire-trade; employment-agriculture; employment-contract; employment-debate; employment-democracy; employment-discrimination; employment-employee; employment-employer; employment-globalization; employment-human rights; employment-manufacturing; employment-poverty; employment-sign; employment-slavery; employment-unemployment; employment-wage; employment-volunteer; employment-workforce; ending-end; endurance-anxiety; endurance-patience; endurance-resilience; enemy-anger; enemy-battle; enemy-devil; enemy-disease; enemy-envy; enemy-evil; enemy-fear; enemy-friend; enemy-friendship; enemy-frustration; enemy-god; enemy-hate; enemy-hatred; enemy-jealousy; enemy-jealousy; enemy-literature; enemy-pact; enemy-propaganda; enemy-protagonist; enemy-religion; enemy-respect; enemy-war; enemy-violence; energy-atmosphere; energy-carbon dioxide; energy-crystal; energy-earthquake; energy-ecology; energy-force; energy-friction; energy-fuel; energy-hail; energy-heat; energy-light; energy-lightning; energy-machine; energy-matter; energy-momentum; energy-mountain; energy-oxygen; energy-potential; energy-pressure; energy-protein; energy-rain; energy-snow; energy-space; energy-speed; energy-star; energy-system; energy-temperature; energy-thermometer; energy-time; energy-tornado; energy-water; energy-wind; energy-volcano; engine-carbon dioxide; engine-carbon footprint; engine-carbon monoxide; engine-cattle; engine-electricity; engine-energy; engine-fluid; engine-force; engine-fuel; engine-gear; engine-global warming; engine-hard drive; engine-heat; engine-horse; engine-liquid; engine-machine; engine-mining; engine-muscle; engine-oxygen; engine-pressure; engine-pump; engine-rocket; engine-ropes; engine-ship; engine-steam; engine-steel; engine-temperature; engine-wind; engineer-accountant; engineer-architect; engineer-business; engineer-education; engineer-engineering; engineer-industry; engineer-lawyer; engineer-management; engineer-pharmacist; engineer-politician; engineer-profession; engineer-science fiction; engineer-scientist; engineer-turkey; engineering-aircraft; engineering-architecture; engineering-artificial intelligence; engineering-biology; engineering-bridge; engineering-canal; engineering-chemistry; engineering-column; engineering-compromise; engineering-computer; engineering-design; engineering-economics; engineering-electricity; engineering-electronics; engineering-energy; engineering-engineer; engineering-harbour; engineering-infrastructure; engineering-logic; engineering-medicine; engineering-philosophy; engineering-physics; engineering-profession; engineering-robot; engineering-science; engineering-simulation; engineering-technology; engineering-telecommunications; engineering-transportation; enjoyment-happiness; enquiry-inquiry; enterprise-business; enterprise-company; enterprise-organization; entertainer-entertainment; entertainment-animation; entertainment-artificial intelligence; entertainment-audience; entertainment-ball; entertainment-ballet; entertainment-baseball; entertainment-basketball; entertainment-birthday; entertainment-board game; entertainment-camping; entertainment-cartoon; entertainment-ceremony; entertainment-chef; entertainment-chess; entertainment-choir; entertainment-circus; entertainment-clown; entertainment-comedian; entertainment-comedy; entertainment-composer; entertainment-concert; entertainment-cooking; entertainment-cricket; entertainment-dance; entertainment-drama; entertainment-education; entertainment-employment; entertainment-fair; entertainment-fantasy; entertainment-festival; entertainment-film; entertainment-fun; entertainment-gambling; entertainment-game; entertainment-ice hockey; entertainment-imagination; entertainment-insight; entertainment-insult; entertainment-irony; entertainment-jazz; entertainment-joke; entertainment-leisure; entertainment-literature; entertainment-marketing; entertainment-millennium; entertainment-monkey; entertainment-music; entertainment-musician; entertainment-novel; entertainment-opera; entertainment-orchestra; entertainment-parade; entertainment-party; entertainment-performance; entertainment-poetry; entertainment-professional; entertainment-public transport; entertainment-radio; entertainment-recreation; entertainment-rhythm; entertainment-running; entertainment-singing; entertainment-sport; entertainment-stadium; entertainment-television; entertainment-theatre; entertainment-tourist; entertainment-tournament; entertainment-warrior; entertainment-wedding; entertainment-video game; entertainment-wit; entertainment-writer; entertainment-zoo; enthusiasm-emotion; enthusiasm-enjoyment; enthusiasm-motivation; enthusiasm-poet; enthusiasm-prayer; entity-ghost; entity-life; entity-matter; entity-spirit; entrance-door; entrance-gate; envelope-government; envelope-mail; envelope-propaganda; envelopment-stem; environment-ecology; environmentalist-sustainability; envy-aggression; envy-anger; envy-competition; envy-faith; envy-green; envy-happiness; envy-jealousy; envy-love; envy-miracle; envy-motivation; envy-priest; envy-resentment; envy-self-esteem; envy-sin; envy-wealth; envy-well-being; envy-virtue; envy-wisdom; episode-drama; episode-edition; episode-news; episode-season; episode-soap opera; equation-addition; equation-formula; equipment-tool; era-music; era-time; erosion-agriculture; erosion-climate change; erosion-drought; erosion-forest; erosion-river; erosion-sky; erosion-soil; erosion-starvation; erosion-stream; erosion-vegetation; error-appeal; error-biology; error-child; error-coin; error-crime; error-design; error-dna; error-engineer; error-evolution; error-gadget; error-government; error-grammar; error-illusion; error-information; error-jury; error-language; error-machine; error-medal; error-noise; error-offspring; error-parent; error-performance; error-pronunciation; error-punctuation; error-runway; error-sin; error-statistics; error-system; error-uncertainty; escalator-airport; escalator-aluminium; escalator-department store; escalator-hotel; escalator-pedestrian; escalator-stadium; escalator-verb; essay-analysis; essay-argument; essay-art; essay-criticism; essay-dissertation; essay-economics; essay-education; essay-metaphor; essay-music; essay-narrative; essay-novel; essay-philosophy; essay-poetry; essay-university; essay-writing; essence-materialism; essence-philosophy; essence-soul; euro-coin; euro-commodity; euro-credit card; euro-debit card; euro-exchange rate; euro-interest; euro-speculation; euro-target; evaluation-bias; evaluation-collaboration; evaluation-consumer; evaluation-controversy; evaluation-credibility; evaluation-customer; evaluation-data; evaluation-dignity; evaluation-education; evaluation-elite; evaluation-experiment; evaluation-goal; evaluation-government; evaluation-health care; evaluation-honesty; evaluation-individual; evaluation-information; evaluation-inquiry; evaluation-insight; evaluation-integrity; evaluation-interest; evaluation-interview; evaluation-knowledge; evaluation-management; evaluation-philosophy; evaluation-policy; evaluation-politics; evaluation-principle; evaluation-privacy; evaluation-questionnaire; evaluation-reality; evaluation-respect; evaluation-security; evaluation-self-esteem; evaluation-statistics; evening-afternoon; evening-dinner; evening-night; evening-sunset; event-business; event-ceremony; event-competition; event-festival; event-news; event-party; event-phenomenon; event-sport; evidence-argument; evidence-arrest; evidence-belief; evidence-bias; evidence-crime; evidence-debate; evidence-experiment; evidence-hypothesis; evidence-knowledge; evidence-laboratory; evidence-law; evidence-observation; evidence-philosophy; evidence-prosecutor; evidence-reason; evidence-resolution; evidence-truth; evidence-validity; evil-criticism; evil-devil; evil-ignorance; evil-murder; evil-neglect; evil-philosophy; evil-rape; evil-selfishness; evil-sin; evil-slavery; evil-terrorism; evolution-adaptation; evolution-ant; evolution-antibiotic; evolution-atmosphere; evolution-bacteria; evolution-bat; evolution-bee; evolution-biology; evolution-bird; evolution-chicken; evolution-crocodile; evolution-dinosaur; evolution-dna; evolution-donkey; evolution-earth; evolution-ecology; evolution-experiment; evolution-extinction; evolution-eye; evolution-fact; evolution-gene; evolution-generation; evolution-global warming; evolution-habitat; evolution-horse; evolution-immune system; evolution-insect; evolution-leg; evolution-life; evolution-mammal; evolution-materialism; evolution-monkey; evolution-mouse; evolution-offspring; evolution-oxygen; evolution-philosopher; evolution-plant; evolution-poet; evolution-population; evolution-protein; evolution-religion; evolution-reptile; evolution-sex; evolution-virus; exaggeration-actor; exaggeration-comedy; exaggeration-evil; exaggeration-gesture; exaggeration-portrait; exaggeration-praise; exaggeration-self-esteem; exaggeration-threat; exchange-rate-bank; exchange-rate-currency; exchange-rate-finance; exchange-rate-inflation; exchange-rate-productivity; exchange-conversation; exchange-trade; exclamation mark-astrophysics; exclamation mark-full stop; exclamation mark-irony; exclamation mark-punctuation; exclamation mark-question mark; exclamation mark-triangle; exhaust-exhaustion; exhibit-exhibition; exhibit-museum; exhibition-archaeology; exhibition-architect; exhibition-chart; exhibition-craft; exhibition-drawing; exhibition-history; exhibition-map; exhibition-museum; exhibition-painting; exhibition-performance; exhibition-science; exhibition-sculpture; exhibition-technology; exhibition-writer; exile-coup; exile-prosecution; exile-refugee; exile-solitude; existence-awareness; existence-belief; existence-consciousness; existence-death; existence-definition; existence-entity; existence-essence; existence-hierarchy; existence-life; existence-materialism; existence-matter; existence-mind; existence-persistence; existence-proposition; existence-reality; existence-sense; existence-world; exit-door; expedition-exploration; expenditure-cost; expense-asset; expense-controversy; expense-cost; expense-debit; expense-employee; expense-expenses; expense-money; expense-tuition; expenses-expense; experience-authority; experience-body; experience-consciousness; experience-customs; experience-data; experience-emotion; experience-empathy; experience-experiment; experience-expert; experience-extreme sports; experience-imagination; experience-individual; experience-intellect; experience-interaction; experience-logic; experience-memory; experience-mind; experience-perception; experience-philosophy; experience-prayer; experience-reality; experience-reason; experience-romour; experience-sense; experience-thought; experience-time; experience-tourism; experience-virtual reality; experience-wisdom; experience-yoga; experiment-agriculture; experiment-astronomy; experiment-chemistry; experiment-ecology; experiment-economics; experiment-engineering; experiment-geology; experiment-hypothesis; experiment-laboratory; experiment-measurement; experiment-number; experiment-philosophy; experiment-protein; experiment-psychology; experiment-science; experiment-scientist; experiment-solution; experiment-statistics; experiment-system; expert-authority; expert-consultant; expert-education; expert-experience; expert-intellectual; expert-judgment; expert-knowledge; expert-law; expert-official; expert-opinion; expert-problem; expert-profession; expert-publication; expert-scholar; expert-skill; expert-technician; expert-training; expert-wisdom; explanation-belief; explanation-description; explanation-exploration; explanation-inquiry; explanation-knowledge; explanation-proposition; explanation-theory; explanation-understanding; exploration-adventure; exploration-explanation; exploration-history; exploration-information; explosion-animal; explosion-bomb; explosion-camera; explosion-chemical; explosion-energy; explosion-flame; explosion-gas; explosion-heat; explosion-missile; explosion-planet; explosion-pressure; explosion-star; explosion-sun; explosion-volcano; explosion-volume; expert-customer; expert-import; expert-management; expert-regulation; exposure-chemical; exposure-publicity; extinction-animal; extinction-biology; extinction-climate change; extinction-death; extinction-dinosaur; extinction-earth; extinction-ecology; extinction-evolution; extinction-global warming; extinction-goat; extinction-government; extinction-habitat; extinction-horse; extinction-mosquito; extinction-philosophy; extinction-plant; extinction-pollution; extinction-population; extinction-predator; extinction-rat; extinction-reproduction; extinction-risk; extinction-selection; extinction-species; extinction-technology; extinction-water; extinction-virus; extinction-zebra; extinction-zoo; extract-alcohol; extract-banana; extract-cherry; extract-grain; extract-lemon; extract-peach; extract-pineapple; extract-prawn; extract-strawberry; extract-water; eye-animal; eye-brain; eye-camera; eye-colour; eye-crystal; eye-darkness; eye-eyelid; eye-fish; eye-horse; eye-light; eye-mirror; eye-prawn; eye-pupil; eye-rabbit; eye-snake; eye-sunlight; eyebrow-anger; eyebrow-mammal; eyebrow-rain; eyebrow-sweat; eyelash-bacteria; eyelash-camel; eyelash-cat; eyelash-cow; eyelash-dust; eyelash-eyelid; eyelash-horse; eyelash-insect; eyelash-mammal; eyelash-mouse; eyelid-antibiotic; eyelid-brow; eyelid-death; eyelid-eyelash; eyelid-brain; face-brain; face-cheek; face-chin; face-communication; face-ear; face-emotion; face-eyebrow; face-eyelash; face-eyelid; face-forehead; face-hair; face-head; face-lip; face-nostril; face-person; face-sense; face-taste; face-temperature; face-tooth; facilities-facility; facility-building; facility-hotel; facility-installation; facility-school; fact-adverb; fact-crime; fact-experience; fact-hypothesis; fact-lie; fact-philosophy; fact-preposition; fact-reality; fact-theory; fact-truth; factory-canal; factory-cotton; factory-globalization; factory-independence; factory-industrialization; factory-interaction; factory-machine; factory-management; factory-manufacturing; factory-organization; factory-paint; factory-public transport; factory-regulation; factory-statistics; factory-tool; factory-tram; factory-warehouse; factory-wheel; failure-competition; failure-disaster; failure-observation; failure-perception; failure-prediction; faith-entertainment; faith-exhibition; faith-festival; faith-harvest; faith-holiday; faith-market; faith-people; faith-justice; faith-belief; faith-confidence; faith-god; faith-knowledge; faith-logic; faith-mind; faith-perception; faith-philosopher; faith-philosophy; faith-probability; faith-psychologist; faith-reason; faith-religion; faith-virtue; faith-deception; faith-forgery; faith-autumn; fame-celebrity; fame-advertising; family-animal; family-aunt; family-belief; family-brother-in-law; family-capitalism; family-city; family-civilization; family-community; family-cousin; family-daughter; family-divorce; family-father; family-grandmother; family-grandparent; family-household; family-human; family-industrialization; family-infant; family-love; family-marriage; family-mother; family-nation; family-nephew; family-niece; family-people; family-region; family-resource; family-science; family-sibling; family-sister-in-law; family-son; family-uncle; family-village; fame-agriculture; fame-bureaucracy; fame-cash; fame-climate; fame-climate change; fame-crime; fame-death; fame-disaster; fame-drought; fame-erosion; fame-farmer; fame-fishing; fame-food; fame-god; fame-grain; fame-hunger; fame-hunting; fame-income; fame-infrastructure; fame-law; fame-leisure; fame-market; fame-mobile phone; fame-money; fame-peasant; fame-refugee; fame-seed; fame-starvation; fame-sustainability; fame-tax; fame-war; fame-vegetarian; fame-wheat; fame-volcano; fantasy-fiction; fantasy-hero; fantasy-history; fantasy-legend; fantasy-literature; fantasy-realm; fantasy-science fiction; fare-airline; fare-bus; fare-fee; fare-passenger; fare-public transport; farm-agriculture; farm-beef; farm-butter; farm-cattle; farm-cheese; farm-chicken; farm-coffee; farm-cotton; farm-cream; farm-democracy; farm-duck; farm-farmer; farm-farming; farm-fibre; farm-food; farm-fuel; farm-grain; farm-lake; farm-mammal; farm-meat; farm-milk; farm-produce; farm-river; farm-sea; farm-socialist; farm-stable; farm-tobacco; farm-tractor;

farmer>agriculture; farmer>cattle; farmer>chicken; farmer>dog; farmer>duck; farmer>employment; farmer>farm; farmer>feather; farmer>gardener; farmer>gardening; farmer>goat; farmer>horse; farmer>market; farmer>meat; farmer>peasant; farmer>poverty; farmer>sheep; farmer>subsidy; farming>agriculture; fashion>beauty; fashion>brand; fashion>clothing; fashion>generation; fashion>geography; fashion>grammar; fashion>language; fashion>logo; fashion>peasant; fashion>perfume; fashion>profession; fashion>society; fashion>turkey; fast food>chicken; fast food>coast; fast food>cucumber; fast food>curry; fast food>cutlery; fast food>ice cream; fast food>junk food; fast food>meat; fast food>menu; fast food>onion; fast food>pancake; fast food>pie; fast food>pizza; fast food>restaurant; fast food>rice; fast food>salad; fast food>sausage; fast food>soft drink; fast food>turkey; fat>butter; fat>chemistry; fat>energy; fat>gram; fat>hair; fat>liquid; fat>mouse; fat>obesity; fat>skin; fat>vitamin; fate>destiny; father>adjective; father>advertisement; father>bear; father>bird; father>cartoon; father>child; father>dolphin; father>duck; father>fish; father>fish; father>housewife; father>human; father>insect; father>lion; father>marriage; father>mother; father>nest; father>parent; father>rape; father>reptile; father>swan; father>verb; father>wolf; fault>error; favourite>architect; favourite>chess; favourite>essay; favourite>mushroom; favourite>prime minister; fear>adaptation; fear>anger; fear>anxiety; fear>bridge; fear>clown; fear>dancing; fear>death; fear>drum; fear>emotion; fear>evil; fear>evolution; fear>failure; fear>fright; fear>future; fear>ghost; fear>happiness; fear>mammal; fear>nightmare; fear>pain; fear>panic; fear>people; fear>psychologist; fear>risk; fear>sadness; fear>singing; fear>snake; fear>solitude; fear>spider; fear>terrorism; fear>threat; fear>tunnel; fear>uncertainty; fear>war; fear>water; feast>festival; feather>beak; feather>bird; feather>blanket; feather>clothing; feather>dinosaur; feather>eagle; feather>eyelash; feather>hair; feather>heat; feather>mammal; feather>parrot; feather>penguin; feather>pillow; feather>pollution; feather>predator; feather>protein; feather>reptile; feather>skin; february>august; february>cabbage; february>day; february>monday; february>month; february>season; february>week; february>year; fee>apartment; fee>cost; fee>flight; fee>illness; fee>interest; fee>lottery; fee>luggage; fee>noise; fee>parking; fee>price; fee>refund; fee>shopping; fee>subsidy; fee>tourism; fee>tuition; fee>upgrade; feedback>electronics; feedback>gain; feedback>gene; feedback>information; feedback>interaction; feedback>investment; feedback>knowledge; feedback>organization; feedback>phenomenon; feedback>protein; feedback>psychology; feedback>revolution; feedback>stock; feedback>stock market; feedback>system; feeling>emotion; feeling>experience; feeling>perception; feeling>touch; female>animal; female>ant; female>bee; female>bird; female>breast; female>evolution; female>genetics; female>girl; female>human; female>insect; female>male; female>mammal; female>milk; female>plant; female>reproduction; female>sex; female>shark; female>woman; female>balcony; female>bridge; female>bull; female>habitat; female>hedge; female>roof; female>transport; fence>wall; fence>water; ferry>boat; ferry>bridge; ferry>global warming; ferry>knot; ferry>ship; ferry>strait; ferry>tunnel; ferry>yacht; festival>fair; festival>god; festival>holiday; festival>idiom; festival>meal; festival>party; festival>religion; festival>season; fever>aspirin; fever>camel; fever>cancer; fever>cold; fever>disease; fever>ear; fever>horse; fever>human; fever>surgery; fever>symptom; fiction>advertising; fiction>author; fiction>biography; fiction>blog; fiction>confusion; fiction>dialogue; fiction>fantasy; fiction>fear; fiction>film; fiction>history; fiction>imagination; fiction>literature; fiction>metaphor; fiction>narrative; fiction>novel; fiction>novel; fiction>poetry; fiction>propaganda; fiction>property; fiction>protagonist; fiction>religion; fiction>school; fiction>science fiction; fiction>song; fiction>symbol; fiction>theatre; fiction>theory; fiction>tragedy; field>lawn; fight>combat; fighting>combat; figure>drawing; figure>number; figure>shape; film>actor; film>advertising; film>amateur; film>animation; film>art; film>ballet; film>camera; film>celebrity; film>cheese; film>commerce; film>culture; film>dialogue; film>documentary; film>download; film>dvd; film>entertainment; film>language; film>magazine; film>newspaper; film>opera; film>orchestra; film>photography; film>piano; film>sound; film>soundtrack; film>subtitles; film>technology; film>television; film>translation; film>asset; finance>bank; finance>business; finance>certainty; finance>economics; finance>inflation; finance>insurance; finance>investment; finance>price; finance>retirement; finance>stock; finger>hand; finger>human; finger>injury; finger>joint; finger>muscle; finger>thumb; finger>toe; fire station>radio; fire>agriculture; fire>atom; fire>candle; fire>chemical; fire>cigarette; fire>coal; fire>cooking; fire>crime; fire>digestion; fire>electricity; fire>firefighter; fire>flame; fire>fuel; fire>habitat; fire>heat; fire>industry; fire>landscape; fire>lead; fire>light; fire>material; fire>oil; fire>school; fire>smoke; fire>temperature; fire>torture; fire>water; fire>vehicle; fire>wood; firefighter>carbon monoxide; firefighter>fuel; firefighter>hazard; firefighter>horse; firefighter>nurse; firefighter>oxygen; firefighter>rescue; fireplace>architecture; fireplace>carbon monoxide; fireplace>chimney; fireplace>lung; fireplace>wood; firm>business; first language>language; fish>adaptation; fish>animal; fish>bee; fish>carbon dioxide; fish>crocody; fish>digestion; fish>fishing; fish>heat; fish>jaw; fish>kidney; fish>liver; fish>mammal; fish>mouth; fish>nostril; fish>oxygen; fish>pain; fish>salmon; fish>shark; fish>skate; fish>species; fish>stomach; fish>suffering; fish>synonym; fish>tuna; fish>vein; fisherman>community; fisherman>culture; fisherman>fish; fisherman>fishing; fisherman>flood; fisherman>shark; fisherman>tuna; fishing>arrow; fishing>beer; fishing>boat; fishing>cod; fishing>community; fishing>crab; fishing>culture; fishing>demand; fishing>ecology; fishing>fish; fishing>fisherman; fishing>market; fishing>miracle; fishing>mouth; fishing>pleasure; fishing>protein; fishing>recreation; fishing>river; fishing>salmon; fishing>sea; fishing>shark; fishing>ship; fishing>tomb; fishing>tuna; fishing>water; fishing>wine; fist>squad; flag>advertising; flag>cargo; flag>communication; flag>country; flag>customs; flag>golf; flag>nation; flag>navy; flag>pollution; flag>referee; flag>shark; flag>socialism; flag>sport; flag>turkey; flag>wave; flag>yacht; flame>air; flame>atmosphere; flame>candle; flame>carbon; flame>carbon monoxide; flame>earth; flame>energy; flame>fire; flame>firework; flame>fuel; flame>gas; flame>heat; flame>industry; flame>laboratory; flame>light; flame>lighter; flame>oxygen; flame>smoke; flame>temperature; flame>wood; flash>lightning; flat>apartment; flesh>animal; flesh>biology; flesh>bone; flesh>fat; flesh>food; flesh>human; flesh>meat; flesh>muscle; flight>air; flight>aircraft; flight>atmosphere; flight>ball; flight>bat; flight>bird; flight>bullet; flight>bullet; flight>density; flight>dinosaur; flight>earth; flight>evolution; flight>firework; flight>force; flight>friction; flight>helicopter; flight>insect; flight>kite; flight>landing; flight>machine; flight>mammal; flight>missile; flight>momentum; flight>penguin; flight>rocket; flight>satellite; flight>ship; flight>skin; flight>species; flight>weight; flood>canal; flood>commerce; flood>civilization; flood>concrete; flood>culture; flood>death; flood>earthquake; flood>farmer; flood>lake; flood>property; flood>river; flood>thunderstorm; flood>tide; flood>water; flood>wind; floor>air conditioning; floor>balcony; floor>carpet; floor>ceiling; floor>employment; floor>soil; floor>storey; flour>bread; flour>cake; flour>carbon dioxide; flour>cereal; flour>coconut; flour>dessert; flour>explosive; flour>flower; flour>grain; flour>ingredient; flour>pancake; flour>pasta; flour>peanut; flour>potato; flour>pudding; flour>rice; flour>root; flour>salt; flour>sauce; flour>wheat; flour>vitamin; flower>adaptation; flower>bee; flower>beer; flower>bird; flower>broccoli; flower>chicken; flower>dna; flower>extinction; flower>female; flower>fruit; flower>funeral; flower>garden; flower>honey; flower>insect; flower>leaf; flower>protein; flower>reproduction; flower>root; flower>rose; flower>seed; flower>spice; flower>symbol; flower>sympathy; flower>temperature; flower>temple; fluency>code; fluency>information; fluency>person; fluency>system; fluency>understanding; fluency>writing; fluid>gas; fluid>liquid; fluid>matter; fluid>physics; fluid>pressure; flute>human; flute>musician; flute>sound; flute>swan; flute>whistle; flute>volume; fly>butterfly; fly>dna; fly>fish; fly>insect; fly>literature; fly>mosquito; fly>novel; fly>poem; fly>species; fly>wound; fog>crystal; fog>hail; fog>ice; fog>mist; fog>slope; fog>smog; fog>steam; fog>valley; fog>water; folk>crowd; folk>ecology; folk>people; folk>tribe; follow>poem; food>acid; food>advertising; food>agriculture; food>animal; food>bacon; food>bacteria; food>bean; food>bee; food>beef; food>blood; food>brand; food>bread; food>broccoli; food>butcher; food>butter; food>cabbage; food>caf ; food>carrot; food>cereal; food>cheese; food>chef; food>chewing gum; food>chicken; food>chocolate; food>climate change; food>commodity; food>cooking; food>corporation; food>counter; food>ecology; food>energy; food>evolution; food>famine; food>fast food; food>fat; food>fish; food>fruit; food>frying pan; food>fuel; food>honey; food>human; food>hygiene; food>immune system; food>import; food>junk food; food>kidney; food>kitchen; food>lemon; food>lettuce; food>meal; food>meat; food>milk; food>muscle; food>mushroom; food>obesity; food>onion; food>oven; food>pasta; food>pea; food>peanut; food>plant; food>pork; food>potato; food>pottery; food>protein; food>rash; food>restaurant; food>rice; food>salad; food>salmon; food>salt; food>seed; food>soup; food>spinach; food>starvation; food>steam; food>sugar; food>supermarket; food>sustainability; food>sweet; food>taste; food>tobacco; food>tomat; food>tool; food>tractor; food>tuna; food>vegetable; food>vegetarian; food>wheat; food>vinegar; food>virus; food>vitamin; food>yogurt; food>clown; food>ankle; food>bone; food>cow; food>heel; foot>hip; foot>horse; foot>infection; foot>knee; foot>leg; foot>muscle; foot>paw; foot>sheep; foot>shoe; foot>sweat; football>basketball; football>blindness; football>gymnastics; football>ice hockey; football>leather; football>peasant; football>professional; football>referee; football>sand; football>sil; football>team; football>tradition; football>try; football>volleyball; football>yard; force>angle; force>atom; force>basketball; force>blog; force>day; force>density; force>diagram; force>earth; force>energy; force>planet; force>flight; force>fluid; force>friction; force>heat; force>interaction; force>logic; force>measurement; force>momentum; force>nature; force>observation; force>physics; force>planet; force>potential; force>pressure; force>revolution; force>second; force>space; force>speed; force>surface; force>temperature; force>wave; force>wind; force>year; forehead>eyebrow; forehead>frown; forehead>wrinkle; forest>bacteria; forest>earth; forest>plant; forest>rainforest; forest>soil; forest>tree; forest>wilderness; forest>woodland; forgery>deception; forgery>document; forgery>fraud; forgery>label; forgery>money; forgery>photography; forgiveness>anger; forgiveness>god; forgiveness>grief; forgiveness>happiness; forgiveness>medicine; forgiveness>murder; forgiveness>punishment; forgiveness>religion; forgiveness>resentment; fork>bronze; fork>cutlery; fork>knife; fork>spoon; form>shape; formula>atom; formula>calculation; formula>computer; formula>equation; formula>ozone; formula>science; formula>sphere; formula>spreadsheet; formula>water; formula>volume; fortnight>day; fortnight>week; fortune>luck; fortune>wealth; fountain>paradise; fountain>pump; fox>animal; fox>berry; fox>bird; fox>continent; fox>dog; fox>extinction; fox>farm; fox>fish; fox>fox; fox>grass; fox>insect; fox>mammal; fox>reptile; fox>snake; fox>species; fox>tail; frame>glasses; fraud>contract; fraud>credit card; fraud>crime; fraud>deception; fraud>money; fraud>stock market; freedom>liberty; frenzy>dvd; frenzy>murder; frenzy>narrative; frenzy>prison; friction>atmosphere; friction>carbon monoxide; friction>copper; friction>experiment; friction>explosion; friction>fluid; friction>force; friction>heat; friction>measurement; friction>road; friction>surface; friction>temperature; friday>corporation; friday>fish; friday>mosque; friday>potato; friday>saturday; friday>sunset; friday>thursday; friend>friendship; friendship>affection; friendship>bird; friendship>cancer; friendship>cat; friendship>cattle; friendship>competition; friendship>discrimination; friendship>divorce; friendship>dog; friendship>empathy; friendship>farmer; friendship>happiness; friendship>honesty; friendship>hospital; friendship>infection; friendship>loyalty; friendship>mail; friendship>mammal; friendship>marriage; friendship>milk; friendship>nickname; friendship>philosophy; friendship>scarcity; friendship>self-esteem; friendship>sympathy; friendship>toy; friendship>understanding; friendship>vaccine; friend>fear; frog>beak; frog>bone; frog>carbon dioxide; frog>climbing; frog>electricity; frog>extinction; frog>eye; frog>fish; frog>heart; frog>kidney; frog>leg; frog>mammal; frog>mouth; frog>oxygen; frog>protein; frog>rib; frog>running; frog>snake; frog>tail; frog>tongue; frog>walking; frog>witch; frontier>border; frontier>turkey; frost>air; frost>crystal; frost>freezer; frost>glass; frost>helicopter; frost>ice; frost>temperature; frost>wind; frost>winter; frown>concentration; frown>confusion; frown>sadness; frown>smile; frown>worry; fruit>agriculture; fruit>animal; fruit>apple; fruit>banana; fruit>bean; fruit>berry; fruit>cake; fruit>carrot; fruit>cereal; fruit>cherry; fruit>coconut; fruit>cookie; fruit>cucumber; fruit>evolution; fruit>flower; fruit>grape; fruit>human; fruit>ice cream; fruit>lemon; fruit>mango; fruit>melon; fruit>nutrition; fruit>olive; fruit>pea; fruit>peach; fruit>peanut; fruit>pear; fruit>pineapple; fruit>rice; fruit>rose; fruit>seed; fruit>spice; fruit>strawberry; fruit>tomat; fruit>water; fruit>vegetable; fruit>wheat; fruit>wine; fruit>vinegar; fruit>yogurt; frustration>anger; frustration>confidence; frustration>disappointment; frustration>fear; frying pan>aluminium; frying pan>bacon; frying pan>copper; fuel>barbecue; fuel>carbon; fuel>carbon dioxide; fuel>carbon monoxide; fuel>cereal; fuel>coal; fuel>diesel; fuel>earth; fuel>electricity; fuel>energy; fuel>engine; fuel>gas; fuel>global warming; fuel>heating; fuel>kilogram; fuel>star; fuel>wheat; fuel>wood; full stop>punctuation; fun>entertainment; fun>happiness; fun>joy; fun>leisure; fun>pleasure; fun>recreation; fun>funding; funding>donation; funding>finance; funding>investment; funding>money; funding>project; funding>savings; funding>subsidy; funding>tax; funeral>burial; funeral>celebrity; funeral>cemetery; funeral>corpse; funeral>culture; funeral>death; funeral>diamond; funeral>flower; funeral>infant; funeral>religion; funeral>ritual; funeral>science fiction; funeral>tom; fun>animal; fun>fox; fun>hair; fun>leather; fun>mammal; fun>rabbit; fun>velvet; fun>wool; furniture>house; furniture>oak; furniture>reform; furniture>sculpture; furniture>turkey; future>architecture; future>earth; future>belief; future>death; future>dimension; future>evolution; future>existence; future>fiction; future>god; future>god; future>history; future>hope; future>information; future>logic; future>materialism; future>mind; future>music; future>nature; future>optimism; future>painting; future>philosophy; future>poetry; future>prediction; future>present; future>probability; future>reality; future>religion; future>risk; future>robot; future>science; future>science fiction; future>sculpture; future>simulation; future>space; future>speed; future>spirit; future>technology; future>theatre; future>theory; future>thesis; future>time; future>uncertainty; future>violence; gadget>electronics; gadget>machine; gadget>novelty; gadget>tool; gain>electronics; gain>ratio; gallery>audience; gallery>balcony; gallery>time; gallery>mining; gallery>museum; gallery>retail; gamble>gambling; gambling>coin; gambling>election; gambling>insurance; gambling>law; gambling>lottery; gambling>money; gambling>probability; gambling>recreation; gambling>speculation; gambling>stock; gambling>television; game>art; game>artificial intelligence; game>baseball; game>basketball; game>board game; game>book; game>chess; game>city; game>competition; game>computer; game>cricket; game>dice; game>education; game>enjoyment; game>entertainment; game>exercise; game>gymnastics; game>hunting; game>interaction; game>lawn; game>leather; game>luck; game>marketing; game>money; game>park; game>psychology; game>puzzle; game>school; game>simulation; game>skill; game>sport; game>strategy; game>table tennis; game>tennis; game>town; game>toy; game>training; game>war; game>video game; game>volleyball; game>harassment; game>ritual; gang>robbery; gang>terrorist; gang>theft; gang>violence; garden>bird; garden>carbon dioxide; garden>climate change; garden>farm; garden>flower; garden>food; garden>fountain; garden>gardener; garden>gardening; garden>insect; garden>landscape; garden>light; garden>lighting; garden>nature; garden>ocean; garden>opera; garden>paradise; garden>park; garden>plant; garden>pollution; garden>rain; garden>sculpture; garden>season; garden>shed; garden>soil; garden>sunshine; garden>trail; garden>tree; garden>water; garden>wildlife; garden>zoo; gardening>garden; gardening>agriculture; gardening>air conditioning; gardening>animal; gardening>ant; gardening>balcony; gardening>basket; gardening>bird; gardening>cat; gardening>civilization; gardening>flower; gardening>fruit; gardening>garden; gardening>herb; gardening>hobby; gardening>hygiene; gardening>insect; gardening>ladder; gardening>lawn; gardening>leaf; gardening>medicine; gardening>plant; gardening>seed;

gardening>spade; gardening>tourism; gardening>tree; gardening>weed; gardening>wildlife; gardening>zoo; garlic>antibiotic; garlic>aspirin; garlic>bird; garlic>blood; garlic>bulb; garlic>cancer; garlic>cholesterol; garlic>glass; garlic>infection; garlic>insect; garlic>iron; garlic>juice; garlic>leek; garlic>onion; garlic>oven; garlic>pasta; garlic>pregnancy; garlic>protein; garlic>tomato; garlic>weed; garlic>vinegar; garlic>worm; garment>conditioning; gas>air; gas>air conditioning; gas>atmosphere; gas>breath; gas>carbon dioxide; gas>chemist; gas>cooking; gas>density; gas>iron; gas>lighting; gas>lightning; gas>liquid; gas>lung; gas>mixture; gas>momentum; gas>oxygen; gas>parachute; gas>particle; gas>pressure; gas>sailling; gas>smoke; gas>statistics; gas>temperature; gas>weather; gas>wind; gate>border; gate>castle; gate>door; gate>fence; gate>road; gate>wall; gear>friction; gear>ratio; gender>biology; gender>breast; gender>butterfly; gender>chemistry; gender>clothing; gender>disability; gender>discrimination; gender>dna; gender>education; gender>gene; gender>genetics; gender>god; gender>history; gender>intelligence; gender>language; gender>nationality; gender>nation; gender>oxygen; gender>protein; gender>psychology; gender>sex; gender>species; gene>ancestor; gene>bacteria; gene>biology; gene>data; gene>dna; gene>electronics; gene>evolution; gene>generation; gene>genetics; gene>hypothesis; gene>infection; gene>life; gene>mouse; gene>pea; gene>protein; gene>region; gene>species; gene>symbol; gene>virus; generalization>animal; generalization>bird; generalization>dog; generalization>fish; generalization>logic; generalization>mammal; generalization>reasoning; generalization>reptile; generalization>triangle; generalization>biology; generalization>career; generalization>child; generalization>childhood; generalization>grandmother; generalization>mother; generalization>offspring; generalization>reproduction; generalization>salary; generosity>gift; generosity>poison; generosity>selfishness; generosity>virtue; genetics>adaptation; genetics>animal; genetics>bacteria; genetics>biology; genetics>cancer; genetics>dna; genetics>evolution; genetics>gene; genetics>health; genetics>health care; genetics>human; genetics>nutrition; genetics>pea; genetics>plant; genetics>protein; genetics>science; genetics>virus; genius>creativity; genius>evolution; genius>expert; genius>insight; genius>intelligence; genius>person; genius>philosopher; genius>statistics; gentleman>business; gentleman>citizen; gentleman>cricket; gentleman>education; gentleman>family; gentleman>honour; gentleman>irony; gentleman>lady; gentleman>prince; gentleman>salary; gentleman>trade; gentleman>university; gentleman>virtue; geography>art; geography>astronomy; geography>climate; geography>communication; geography>culture; geography>database; geography>earth; geography>economics; geography>geology; geography>globalization; geography>horizon; geography>human; geography>interaction; geography>map; geography>mountain; geography>planet; geography>politics; geography>science; geography>soil; geography>space; geography>sustainability; geography>transport; geography>university; geography>valley; geography>water; geology>atmosphere; geology>climate change; geology>earth; geology>earthquake; geology>erosion; geology>evolution; geology>floor; geology>geography; geology>intrusion; geology>landscape; geology>metal; geology>mining; geology>mountain; geology>museum; geology>river; geology>science; geology>volcano; gerund>adjective; gerund>adverb; gerund>clause; gerund>infinitive; gerund>noun; gerund>phrase; gerund>preposition; gerund>verb; gesture>dance; gesture>face; gesture>hand; gesture>speech; gesture>word; ghost>analogy; ghost>animal; ghost>classic; ghost>fear; ghost>fiction; ghost>god; ghost>mind; ghost>perception; ghost>religion; ghost>sacrifice; ghost>sleep; ghost>spirit; gift>baby; gift>birthday; gift>boyfriend; gift>bribery; gift>cake; gift>drink; gift>economics; gift>examination; gift>father; gift>food; gift>forgiveness; gift>friendship; gift>funeral; gift>girlfriend; gift>happiness; gift>kindness; gift>love; gift>money; gift>mother; gift>property; gift>retirement; gift>sacrifice; gift>souvenir; gift>student; gift>wedding; giraffe>animal; giraffe>camel; giraffe>leopard; giraffe>lion; giraffe>mammal; giraffe>rib; giraffe>skull; giraffe>tick; giraffe>woodland; girl>adult; girl>boy; girl>childhood; girl>confirmation; girl>education; girl>female; girl>girlfriend; girl>human; girl>man; girl>woman; girlfriend>boyfriend; girlfriend>friendship; girlfriend>marriage; girlfriend>wedding; glass>bottle; glass>carbon; glass>carbon dioxide; glass>chemical; glass>crystal; glass>lightning; glass>sand; glass>telescope; glass>vase; glass>>window; glass>volume; glasses>blindness; glasses>chef; glasses>department store; glasses>ear; glasses>fashion; glasses>glass; glasses>hat; glasses>laser; glasses>light; glasses>pharmacy; glasses>plastic; glasses>radiation; glasses>sunglasses; glasses>virtual reality; global warming>atmosphere; global warming>carbon dioxide; global warming>cloud; global warming>desert; global warming>energy; global warming>extinction; global warming>flood; global warming>ice; global warming>ocean; global warming>ozone; global warming>planet; global warming>plant; global warming>probability; global warming>rice; global warming>satellite; global warming>snow; global warming>society; global warming>soil; global warming>statistics; global warming>summer; global warming>technology; global warming>volcano; globalization>accountant; globalization>airline; globalization>banking; globalization>business; globalization>capitalism; globalization>carbon dioxide; globalization>cash; globalization>climate change; globalization>communication; globalization>community; globalization>construction; globalization>crime; globalization>culture; globalization>curriculum; globalization>democracy; globalization>earth; globalization>economics; globalization>economist; globalization>exchange rate; globalization>famine; globalization>fast food; globalization>finance; globalization>global warming; globalization>habitat; globalization>health; globalization>human rights; globalization>immigration; globalization>import; globalization>income; globalization>industrialization; globalization>innovation; globalization>insurance; globalization>investment; globalization>investor; globalization>knowledge; globalization>leisure; globalization>liberty; globalization>life; globalization>marriage; globalization>nature; globalization>passport; globalization>peasant; globalization>philosophy; globalization>pollution; globalization>propaganda; globalization>recreation; globalization>religion; globalization>river; globalization>socialism; globalization>society; globalization>solidarity; globalization>sustainability; globalization>tax; globalization>technology; globalization>the internet; globalization>tiger; globalization>tourism; globalization>trade; globalization>transport; globalization>transportation; globalization>travel; globalization>war; globalization>wealth; globe>baseball; globe>child; globe>cigarette; globe>confirmation; globe>cricket; globe>cycling; globe>evidence; globe>fashion; globe>finger; globe>garden; globe>gardening; globe>garment; globe>hand; globe>heat; globe>leaf; globe>leather; globe>patient; globe>silks; globe>silver; globe>skateboard; globe>ski; globe>steering wheel; globe>thumb; globe>wheelchair; globe>wool; globe>wrist; globe>belief; globe>commerce; globe>cost; globe>customer; globe>emotion; globe>motivation; globe>person; globe>system; goalkeeper>ice hockey; goalkeeper>sport; goat>adolescent; goat>animal; goat>butter; goat>cattle; goat>cheese; goat>cow; goat>curry; goat>devil; goat>erosion; goat>fish; goat>ice cream; goat>iron; goat>litre; goat>mammal; goat>milk; goat>spring; goat>pet; goat>poverty; goat>religion; goat>saint; goat>sausage; goat>sheep; goat>spoon; goat>starvation; goat>tree; goat>weed; goat>vine; goat>wine; goat>yogurt; god>angel; god>body; god>existence; god>faith; god>gender; god>nature; god>necessity; god>plural; god>reason; god>revelation; god>saint; god>simplicity; god>soap opera; god>turkey; god>world; god>worship; gold>aluminium; gold>bronze; gold>cancer; gold>chemistry; gold>coin; gold>computer; gold>copper; gold>currency; gold>electronics; gold>evil; gold>geology; gold>icon; gold>inflation; gold>iron; gold>lead; gold>metal; gold>money; gold>ocean; gold>receipt; gold>satellite; gold>silver; gold>sun; gold>tin; gold>trophy; gold>vehicle; gold>weight; golf>sport; gossip>blackmail; gossip>celebrity; gossip>community; gossip>curiosity; gossip>information; gossip>popularity; gossip>reputation; gossip>scandal; gossip>self-esteem; gossip>sin; government>alliance; government>bureaucracy; government>capitalism; government>constitution; government>corruption; government>democracy; government>economics; government>election; government>empire; government>fear; government>hate; government>history; government>hospital; government>human rights; government>jury; government>liberty; government>majority; government>philosophy; government>police; government>policy; government>politics; government>public; government>school; government>science; government>science fiction; government>socialism; government>synonym; government>terrorist; gram>kilogram; gram>metre; gram>water; grammar>communication; grammar>education; grammar>first language; grammar>learning; grammar>nationality; grammar>observation; grammar>phrase; grammar>primary school; grammar>punctuation; grammar>usage; grandchild>family; granddad>grandparent; granddaughter>family; grandfather>grandparent; grandma>grandparent; grandmother>grandparent; grandpa>grandparent; grandparents>aunt; grandparents>child; grandparents>cousin; grandparents>father; grandparents>gene; grandparents>mother; grandparents>parent; grandparents>plural; grandparents>uncle; grandparents>family; granny>chimney; granny>grandparent; grape>agriculture; grape>berry; grape>brain; grape>cancer; grape>fruit; grape>heart; grape>jam; grape>nerve; grape>vine; grape>wine; grape>vinegar; grape>virus; graph>chart; graph>diagram; graphics>animation; graphics>art; graphics>brand; graphics>business; graphics>concept; graphics>drawing; graphics>economics; graphics>engineering; graphics>game; graphics>geography; graphics>idea; graphics>illustration; graphics>image; graphics>newspaper; graphics>number; graphics>painting; graphics>paper; graphics>photograph; graphics>poster; graphics>science; graphics>space; graphics>symbol; graphics>video game; grass>hand; grass>animal; grass>baseball; grass>beer; grass>cattle; grass>cereal; grass>clothing; grass>construction; grass>cricket; grass>desert; grass>dinosaur; grass>wood; grass>drought; grass>fuel; grass>golf; grass>grain; grass>horse; grass>human; grass>kangaroo; grass>lawn; grass>paper; grass>plant; grass>rabbit; grass>rice; grass>sheep; grass>suburb; grass>tennis; grass>wheat; grass>whisky; grave>archaeology; grave>burial; grave>cemetery; grave>culture; grave>pyramid; grave>religion; grave>soul; greatness>genius; greed>authority; greed>popularity; greed>robbery; green>blue; green>copper; green>devil; green>envy; green>experience; green>firework; green>fish; green>frog; green>gambling; green>grass; green>greed; green>health; green>hope; green>illness; green>insomnia; green>jealousy; green>laser; green>lead; green>leek; green>money; green>nature; green>perception; green>prostitute; green>protein; green>purple; green>red; green>traffic light; green>white; green>yellow; green>youth; greeting>culture; greeting>gesture; greeting>hug; greeting>telephone; greeting>tradition; grey>baseball; grey>black; grey>blue; grey>brain; grey>earth; grey>environmentalist; grey>fog; grey>green; grey>intellectual; grey>lead; grey>pink; grey>prayer; grey>profession; grey>red; grey>religion; grey>speed; grey>white; grey>yellow; grief>deer; grief>elephant; grief>laughter; grief>lion; grief>professor; grief>psychiatrist; grief>psychologist; grief>suicide; grief>terrorism; grief>widow; grill>restaurant; grin>smile; groom>bride; groom>spouse; ground>coffee; ground>law; ground>philosophy; ground>soil; ground>stadium; group>enemy; group>friend; group>gang; group>immigrant; group>nationality; group>organization; group>supporter; growth>height; growth>interest; growth>money; guard>police; guest>hospitality; guidance>guide; guide>culture; guide>ecology; guide>fishing; guide>hunting; guide>salmon; guide>sport; guide>wilderness; guitar>bone; guitar>brass; guitar>cable; guitar>cello; guitar>folk; guitar>jazz; guitar>jazz; guitar>leather; guitar>radio; guitar>radio; guitar>violin; guitarist>finger nail; guitarist>guitar; guitarist>jazz; guitarist>magazine; guitarist>singing; guitarist>website; gum>chewing gum; gun>sound; gun>weapon; gym>curriculum; gym>education; gym>gymnastics; gymnastics>ballet; gymnastics>dance; gymnastics>sport; habit>habitat; habitat>animal; habitat>plant; habitat>predator; habitat>species; hail>airport; hail>atmosphere; hail>ice; hail>rocket; hail>thunderstorm; hail>tornado; hail>water; hail>wind; hair>blade; hair>cat; hair>communication; hair>dir; hair>dust; hair>ear; hair>euro; hair>eyebrow; hair>eyelash; hair>face; hair>fur; hair>gender; hair>haircut; hair>hand; hair>mammal; hair>milk; hair>punishment; hair>rain; hair>scissors; hair>sweat; hairdresser>barber; hairdresser>comb; hairdresser>electricity; hairdresser>hair; hairdresser>scissors; hairdresser>slavery; hairdresser>spirit; hall>apartment; hall>architecture; hall>building; hall>castle; hall>college; hall>community; hall>corridor; hall>kitchen; hall>library; hall>office; hall>theatre; hall>university; ham>cholesterol; ham>meat; ham>protein; ham>sandwich; ham>steak; ham>bone; ham>force; ham>muscle; ham>speed; ham>tool; ham>war; hammer>weapon; hammer>wood; hand>animal; hand>bird; hand>dinosaur; hand>evolution; hand>finger; hand>foot; hand>grasp; hand>human; hand>mammal; hand>medicine; hand>monkey; hand>paw; hand>skeleton; hand>thumb; hand>wrist; handbag>coin; handbag>contraception; handbag>crocodile; handbag>mobile phone; handbag>security; handbag>strap; handbag>wallet; handkerchief>cotton; handkerchief>fashion; handkerchief>hand; handkerchief>handbag; handkerchief>hygiene; handkerchief>linen; handkerchief>pocket; handkerchief>silks; hand>gambling; handout>college; handout>gift; handout>homelessness; handout>welfare; handwriting>signature; happiness>biology; happiness>philosophy; happiness>pleasure; happiness>psychology; happiness>religion; happiness>symbol; happiness>well-being; happiness>virtue; harassment>discrimination; harm>medal; harm>death; harm>disability; harm>law; harm>liberty; harm>pain; harm>pleasure; harm>skill; harm>well-being; harm>jazz; harmony>melody; harmony>music; harmony>performance; harmony>tradition; harvest>agriculture; harvest>cereal; harvest>crop; harvest>energy; harvest>farm; harvest>fish; harvest>grain; harvest>season; harvest>timber; harvest>wine; hat>cotton; hat>cricket; hat>face; hat>ribbon; hat>sheep; hat>ski; hat>straw; hat>wool; hate>hated; hate>anger; hate>crime; hate>disability; hate>discrimination; hate>emotion; hate>gender; hate>gossip; hate>harassment; hate>global warming; hate>nationality; hate>prejudice; hate>religion; hate>revenge; hate>sex; hazard>accident; hazard>chemical; hazard>disaster; hazard>emergency; hazard>language; hazard>health; hazard>life; hazard>possibility; hazard>property; hazard>punishment; hazard>risk; hazard>volcano; head>brain; head>ear; head>eye; head>face; head>food; head>nose; head>taste; headache>anxiety; headache>boy; headache>cancer; headache>child; headache>cough; headache>diary; headache>fever; headache>flood; headache>head; headache>infection; headache>medication; headache>neck; headache>nerves; headache>pain; headache>sleep; headache>stroke; headache>symptom; headache>water; headache>weather; headache>virus; heading>headline; heading>volleyball; headline>humour; headline>publisher; headquarters>corporation; headquarters>finance; headquarters>marketing; headquarters>organization; headquarters>turkey; health care>cancer; health care>clinic; health care>diagnosis; health care>disability; health care>disease; health care>donation; health care>health; health care>hospital; health care>illness; health care>insurance; health care>medicine; health care>nurse; health care>pharmacist; health care>physician; health care>professional; health care>regulation; health care>surgery; health care>vaccination; health care>health care>wheelchair; health>air; health>alcohol; health>biology; health>body; health>child; health>continent; health>country; health>culture; health>disease; health>education; health>exercise; health>gender; health>genetics; health>health care; health>house; health>human; health>hygiene; health>illness; health>injury; health>literacy; health>manufacturing; health>medicine; health>nutrition; health>obesity; health>outbreak; health>pain; health>person; health>pharmacy; health>physics; health>psychology; health>research; health>safety; health>sleep; health>smoking; health>vaccination; health>water; health>well-being; health>world; heart>bird; heart>blood; heart>copper; heart>crab; heart>fat; heart>insect; heart>iron; heart>liver; heart>lung; heart>mammal; heart>muscle; heart>protein; heart>reptile; heart>spider; heart>sugar; heart>vein; heat>chemistry; heat>energy; heat>engineering; heat>kilogram; heat>life; heat>physics; heat>steam; heat>sun; heat>temperature; heat>thermometer; heaven>angel; heaven>earth; heaven>faith; heaven>fiction; heaven>god; heaven>hell;

heaven>nature; heaven>paradise; heaven>prayer; heaven>science fiction; heaven>sin; heaven>sky; heaven>virtue; hedge>century; hedge>climate; hedge>count; hedge>fence; hedge>flower; hedge>garden; hedge>privacy; hedge>road; hedge>wildlife; heel>foot; heel>knee; height>dimension; height>distance; height>genetics; height>length; height>mountain; height>nutrition; height>pie; height>statistics; height>width; heir>inheritance; helicopter>ambulance; helicopter>flight; helicopter>mechanic; helicopter>recreation; helicopter>tourism; helicopter>transport; hell>atmosphere; hell>cartoon; hell>death; hell>devil; hell>earth; hell>fantasy; hell>god; hell>heaven; hell>hypocrite; hell>paradise; hell>punishment; hell>religion; hell>sin; hell>sky; hell>soul; hell>torment; helmet>arrow; helmet>bronze; helmet>cap; helmet>construction; helmet>iron; helmet>leather; helmet>mining; helmet>plastic; helmet>steel; helmet>straw; helmet>sunglasses; helmet>sword; helmet>tank; help>emergency; herb>bark; herb>berry; herb>flower; herb>food; herb>fruit; herb>leaf; herb>religion; herb>root; herb>seed; herb>spice; herb>tree; herb>vegetable; heritage>birth; heritage>inheritance; hero>archaeology; hero>biography; hero>civilization; hero>courage; hero>economics; hero>endurance; hero>fantasy; hero>film; hero>geography; hero>globalization; hero>protagonist; hero>quest; hero>warrior; hesitation>pause; hierarchy>animation; hierarchy>atom; hierarchy>authority; hierarchy>carbon; hierarchy>chest; hierarchy>colleague; hierarchy>complexity; hierarchy>concept; hierarchy>diagram; hierarchy>diamond; hierarchy>dimension; hierarchy>entity; hierarchy>god; hierarchy>government; hierarchy>hand; hierarchy>heir; hierarchy>hell; hierarchy>human; hierarchy>importance; hierarchy>individual; hierarchy>inheritance; hierarchy>learning; hierarchy>matter; hierarchy>music; hierarchy>nation; hierarchy>nature; hierarchy>object; hierarchy>organization; hierarchy>parent; hierarchy>structure; hierarchy>supervisor; hierarchy>system; hierarchy>triangle; hierarchy>university; hierarchy>verb; hill>cheese; hill>erosion; hill>geology; hill>golf; hill>mountain; hill>soil; hill>volcano; hip>birth; hip>fashion; hip>joint; hip>shoulder; historian>archaeology; historian>economics; historian>narrative; historian>philosophy; historian>politics; historian>psychology; historian>seminar; history>archaeology; history>art; history>communication; history>continent; history>credibility; history>culture; history>decade; history>economics; history>evidence; history>experience; history>fantasy; history>gender; history>geography; history>historian; history>imagination; history>information; history>integrity; history>legend; history>memory; history>narrative; history>philosophy; history>poetry; history>politics; history>poverty; history>propaganda; history>reason; history>science; history>theory; hobby>air conditioning; hobby>amateur; hobby>art; hobby>balcony; hobby>book; hobby>climbing; hobby>comic; hobby>cooking; hobby>dancing; hobby>digestion; hobby>enthusiasm; hobby>fire; hobby>fishing; hobby>gardener; hobby>gardening; hobby>gardening; hobby>heating; hobby>hill; hobby>house; hobby>journalism; hobby>label; hobby>landscape; hobby>leisure; hobby>literature; hobby>magazine; hobby>newspaper; hobby>park; hobby>photography; hobby>pottery; hobby>professional; hobby>recreation; hobby>robot; hobby>singing; hobby>tourism; hobby>tool; hobby>tourism; hobby>vocabulary; hockey>ball; hockey>disability; hockey>ice hockey; hockey>sport; hockey>tennis; hold>grasp; hole>opening; holiday>faith; holiday>religion; home>apartment; home>city; home>cooking; home>country; home>emotion; home>family; home>habitat; home>hat; home>homelessness; home>household; home>institution; home>prison; home>residence; home>safety; home>suburb; home>town; homelessness>airport; homelessness>bus; homelessness>caf  ; homelessness>college; homelessness>disability; homelessness>disaster; homelessness>dissertation; homelessness>earthquake; homelessness>hotel; homelessness>hypocrisy; homelessness>litter; homelessness>male; homelessness>park; homelessness>poverty; homelessness>prison; homelessness>running; homelessness>tent; homelessness>unemployment; homelessness>van; homelessness>war; homework>computer; homework>education; homework>essay; homework>learning; homework>research; homework>school; homework>student; homework>teacher; homework>teaching; homework>writing; honesty>fair; honesty>integrity; honesty>lie; honesty>loyalty; honesty>proverb; honesty>truth; honey>acid; honey>bee; honey>beer; honey>bread; honey>cooking; honey>cotton; honey>crystal; honey>density; honey>dust; honey>food; honey>glass; honey>ladder; honey>milk; honey>pollution; honey>solution; honey>sugar; honey>symbol; honey>tea; honey>turkey; honey>water; honey>vitamin; honeymoon>pleasure; honeymoon>wedding; honour>cash; honour>celebrity; honour>conscience; honour>crime; honour>culture; honour>dignity; honour>family; honour>frontier; honour>gang; honour>government; honour>individual; honour>integrity; honour>law; honour>love; honour>lyrics; honour>medal; honour>nation; honour>privilege; honour>property; honour>rape; honour>reputation; honour>revenge; honour>school; honour>shame; honour>society; honour>stereotype; honour>turkey; honour>virtue; hope>disappointment; hope>fantasy; hope>fear; hope>heaven; hope>optimism; hope>psychology; horizon>circle; horizon>communication; horizon>dawn; horizon>earth; horizon>landscape; horizon>radio; horizon>sky; horizon>storey; horse>saddle; horn>telephone; horse>advertising; horse>animal; horse>ankle; horse>cello; horse>cereal; horse>concept; horse>donkey; horse>extinction; horse>family; horse>farm; horse>gene; horse>genetics; horse>heel; horse>instinct; horse>mammal; horse>pony; horse>prison; horse>reptile; horse>saddle; horse>stable; horse>vaccination; horse>water; horse>violin; horse>wrist; hospital>ambulance; hospital>business; hospital>campus; hospital>cathedral; hospital>clinic; hospital>diagnosis; hospital>disease; hospital>grammar; hospital>health; hospital>health care; hospital>hospitality; hospital>hostel; hospital>hotel; hospital>injury; hospital>mosque; hospital>nurse; hospital>partnership; hospital>patient; hospital>surgeon; hospital>surgery; hospital>entertainment; host>hospitality; host>presenter; hostage>crime; hostage>employer; hostage>government; hostage>metaphor; hostage>police officer; hostage>terrorism; hostage>turkey; hotel>carnival; hotel>castle; hotel>climbing; hotel>travel; hostility>aggression; hostility>anger; hostility>denial; hostility>synonym; hotel>air conditioning; hotel>cave; hotel>define article; hotel>investor; hotel>resort; hotel>telephone; hotel>tourism; hotel>turkey; hour>century; hour>clock; hour>energy; hour>minute; hour>opera; hour>public transport; hour>second; hour>speed; hour>tide; hour>time; hour>wage; house>architect; house>architect; house>basement; house>bathroom; house>bedroom; house>brick; house>building; house>comfort; house>concrete; house>construction; house>dining room; house>door; house>earthquake; house>economics; house>family; house>fireplace; house>hall; house>home; house>household; house>human; house>kitchen; house>lead; house>library; house>living room; house>loft; house>office; house>pet; house>privacy; house>prosperity; house>shower; house>staircase; house>technology; house>television; house>toilet; house>weather; house>wildlife; house>>window; house>wood; house>workshop; household>disability; household>employment; household>family; household>government; household>home; household>housework; household>income; household>inheritance; household>living room; household>meal; housewife>career; housewife>cooking; housewife>economist; housewife>employment; housewife>factory; housewife>family; housewife>farming; housewife>fruit; housewife>grain; housewife>home; housewife>homework; housewife>household; housewife>nutrition; housewife>rice; housewife>sewing; housewife>vegetable; housewife>volunteer; housing>home; housing>house; hug>affection; hug>arm; hug>child; hug>dog; hug>doll; hug>dolphin; hug>greeting; hug>hip; hug>kiss; hug>love; hug>sympathy; hug>teenager; human rights>abortion; human rights>belief; human rights>capitalism; human rights>child; human rights>climate change; human rights>concept; human rights>contraception; human rights>discrimination; human rights>education; human rights>justice; human rights>peace; human rights>religion; human rights>right; human rights>socialism; human rights>treaty; human rights>violence; human rights>woman; human rights>worship; human>adult; human>agriculture; human>aircraft; human>archaeology; human>art; human>artificial intelligence; human>belief; human>boy; human>bureaucracy; human>buyer; human>childhood; human>city; human>civilization; human>climate change; human>clothing; human>comedy; human>commodity; human>communication; human>competition; human>consciousness; human>construction; human>continent; human>cooking; human>crime; human>culture; human>democracy; human>digestion; human>discipline; human>discussion; human>drama; human>dream; human>duty; human>earnings; human>earring; human>earth; human>economics; human>empire; human>entertainment; human>envy; human>evolution; human>exercise; human>existence; human>family; human>female; human>fire; human>gene; human>genetics; human>girl; human>global warming; human>globalization; human>god; human>government; human>hair; human>happiness; human>hate; human>health; human>hierarchy; human>humanity; human>hunting; human>idea; human>incentive; human>information; human>jealousy; human>language; human>law; human>literature; human>logic; human>love; human>male; human>mammal; human>man; human>manufacturing; human>market; human>marriage; human>mind; human>mobile phone; human>motivation; human>narrative; human>nation; human>obesity; human>painting; human>perception; human>philosopher; human>philosophy; human>pleasure; human>politics; human>pollution; human>pottery; human>privilege; human>psychology; human>question; human>racism; human>reason; human>reasoning; human>religion; human>reproduction; human>revolution; human>ritual; human>science; human>self-awareness; human>seller; human>sense; human>sleep; human>society; human>soldier; human>soul; human>space; human>species; human>spirit; human>suffering; human>technology; human>thought; human>tool; human>trade; human>tragedy; human>transport; human>tribe; human>wealth; human>vegetarian; human>violence; human>woman; humanity>human; humility>god; humility>pride; humility>strategy; humility>truth; humility>virtue; humility>wisdom; humour>ambiguity; humour>amusement; humour>comedy; humour>contradiction; humour>culture; humour>education; humour>intelligence; humour>irony; humour>metaphor; humour>paradox; humour>psychology; humour>reality; humour>smile; hunger>disease; hunger>famine; hunger>food; hunger>starvation; hunting>arrow; hunting>bat; hunting>bear; hunting>bone; hunting>deer; hunting>environmentalist; hunting>extinction; hunting>fish; hunting>fishing; hunting>fox; hunting>fur; hunting>habit; hunting>infrastructure; hunting>jungle; hunting>language; hunting>lead; hunting>lion; hunting>mammal; hunting>pig; hunting>predator; hunting>prison; hunting>protein; hunting>rabbit; hunting>recreation; hunting>regulation; hunting>ritual; hunting>trophy; hunting>webcam; hunting>wildlife; hunting>wolf; husbands>authority; husbands>crime; husbands>divorce; husbands>father; husbands>male; husbands>marriage; husbands>profession; husbands>society; husbands>spouse; husband>wedding; husband>wife; hygiene>acre; hygiene>bandage; hygiene>cap; hygiene>cold; hygiene>cooking; hygiene>culture; hygiene>cutlery; hygiene>flu; hygiene>gender; hygiene>hairdresser; hygiene>health; hygiene>perfume; hygiene>scent; hygiene>shower; hygiene>soap; hygiene>surgery; hygiene>toilet; hyphen>adjective; hyphen>adverb; hyphen>comma; hyphen>dash; hyphen>punctuation; hyphen>recreation; hyphen>surname; hyphen>syllable; hyphen>word; hypocrite>irony; hypocrite>paradox; hypothesis>calculation; hypothesis>concept; hypothesis>entity; hypothesis>experience; hypothesis>experiment; hypothesis>explanation; hypothesis>laboratory; hypothesis>logic; hypothesis>nature; hypothesis>observation; hypothesis>phenomenon; hypothesis>prediction; hypothesis>proposition; hypothesis>reasoning; hypothesis>research; hypothesis>theory; hypothesis>virtue; ice cream>chocolate; ice cream>cream; ice cream>crystal; ice cream>dessert; ice cream>juice; ice cream>milk; ice cream>pension; ice cream>protein; ice cream>sugar; ice cream>yogurt; ice hockey>cricket; ice hockey>ice skating; ice hockey>recreation; ice skating>empire; ice skating>helmet; ice skating>ice; ice skating>ice hockey; ice skating>steel; ice>air; ice>atom; ice>carbon dioxide; ice>cloud; ice>crystal; ice>density; ice>dirt; ice>dust; ice>fog; ice>frost; ice>hail; ice>heat; ice>ice hockey; ice>ice skating; ice>lake; ice>liquid; ice>metal; ice>oxygen; ice>road; ice>soil; ice>thunderstorm; ice>truck; ice>water; ice>>window; iceberg>density; iceberg>erosion; iceberg>satellite; icon>angel; icon>miracle; icon>paper; icon>peasant; icon>saint; icon>symbol; idea>concept; idea>creativity; idea>evolution; idea>experiment; idea>fish; idea>gene; idea>horse; idea>human; idea>image; idea>imagination; idea>liberty; idea>man; idea>memory; idea>perception; idea>property; idea>psychologist; idea>selection; idea>understanding; idea>woman; identity>entity; idiom>clich  ; idiom>collocation; idiom>definition; idiom>verb; idiot>democracy; idiot>government; idiot>ignorance; idiot>stupidity; idol>worship; ignorance>awareness; ignorance>innocence; ignorance>knowledge; ignorance>literacy; ignorance>stupidity; ignorance>wisdom; illusion>perception; illusion>sense; illusion>sound; illustration>diagram; illustration>drawing; illustration>image; illustration>ink; illustration>painting; illustration>pen; illustration>photograph; illustration>video game; image>animation; image>camera; image>dimension; image>drawing; image>film; image>graphics; image>map; image>mirror; image>painting; image>paper; image>person; image>photograph; image>photography; image>status; image>telescope; image>video; imagination>art; imagination>belief; imagination>creativity; imagination>fantasy; imagination>fear; imagination>fiction; imagination>hypothesis; imagination>idea; imagination>language; imagination>mind; imagination>myth; imagination>narrative; imagination>perception; imagination>pleasure; imagination>probability; imagination>psychology; imagination>science fiction; imagination>suffering; imagination>truth; imitation>animal; imitation>curiosity; imitation>empathy; imitation>expert; imitation>information; imitation>intelligence; imitation>intention; imitation>learning; imitation>purpose; imitation>rat; imitation>reproduction; imitation>science; imitation>scientist; imitation>species; immigrant>immigration; immigration>arrest; immigration>citizen; immigration>climate; immigration>constitution; immigration>education; immigration>employment; immigration>human rights; immigration>poverty; immigration>racism; immigration>refugee; immigration>retirement; immigration>terrorism; immigration>tourist; immigration>war; immune system>acid; immune system>animal; immune system>antibiotic; immune system>bacteria; immune system>blood; immune system>cancer; immune system>cough; immune system>disease; immune system>evolution; immune system>fever; immune system>gene; immune system>infant; immune system>infection; immune system>insect; immune system>irritation; immune system>leaf; immune system>lung; immune system>mammal; immune system>medicine; immune system>obesity; immune system>plant; immune system>pregnancy; immune system>skin; immune system>stomach; immune system>vaccination; immune system>vaccine; immune system>virus; impatience>patience; implementation>bureaucracy; implementation>code; implementation>design; implementation>plan; implementation>policy; implementation>solution; implementation>specification; implementation>system; imports>commodity; imports>consumer; imports>customs; imports>export; imports>income; imports>manufacturer; imports>price; imports>trade; impossibility>contract; impossibility>necessity; imprisonment>liberty; incentive>competition; incentive>corporation; incentive>curiosity; incentive>employment; incentive>slavery; incentive>volunteer; inch>centimetre; inch>length; inch>metre; inch>millimetre; inch>yard; income>economics; income>education; income>peace; income>society; independence>authority; independence>revolution; independence>nation; independence>obedience; independence>status; independence>violence; indication>sign; individual>biology; individual>consciousness; individual>gene; individual>independence; individual>law; individual>person; individual>philosophy; individual>selection; individual>statistics; individuality>individual; industry>agriculture; industry>carriage; industry>coal; industry>computer; industry>economy; industry>electricity; industry>finance; industry>manufacturing; industry>market; industry>pollution; industry>robot; industry>steel; infancy>infant; infant>adaptation; infant>bruise; infant>health; infant>hospital; infant>human; infant>infection; infant>milk; infant>offspring; infant>pregnancy; infant>toddler; infection>antibiotic; infection>bacteria; infection>blood; infection>body; infection>disease; infection>fever;

infection>hygiene; infection>immune system; infection>joint; infection>mammal; infection>medicine; infection>symptom; infection>vaccination; infection>virus; infection>wound; infinitive>adverb; infinitive>clause; infinitive>gerund; infinitive>grammar; infinitive>noun; infinitive>verb; inflation>commodity; inflation>currency; inflation>demand; inflation>economics; inflation>exchange rate; inflation>inflation; inflation>inflation; inflation>investment; inflation>ratio; inflation>recession; inflation>scarcity; inflation>stock; inflation>stock market; inflation>unemployment; information>bit; information>cd-rom; information>communication; information>complexity; information>concept; information>data; information>dna; information>education; information>energy; information>feedback; information>form; information>knowledge; information>message; information>perception; information>physics; information>prediction; information>proposition; information>relevance; information>sequence; information>system; information>thought; information>uncertainty; information>understanding; infrastructure>airline; infrastructure>ambulance; infrastructure>architect; infrastructure>architecture; infrastructure>bridge; infrastructure>bus; infrastructure>business; infrastructure>city; infrastructure>climate change; infrastructure>coal; infrastructure>college; infrastructure>commerce; infrastructure>communication; infrastructure>consent; infrastructure>contract; infrastructure>corporation; infrastructure>cost; infrastructure>earthquake; infrastructure>economy; infrastructure>electricity; infrastructure>energy; infrastructure>exchange; infrastructure>factory; infrastructure>ferry; infrastructure>government; infrastructure>health care; infrastructure>hospital; infrastructure>institution; infrastructure>library; infrastructure>manufacturing; infrastructure>market; infrastructure>mobile phone; infrastructure>museum; infrastructure>nation; infrastructure>noise; infrastructure>organization; infrastructure>ownership; infrastructure>park; infrastructure>police; infrastructure>port; infrastructure>poverty; infrastructure>primary school; infrastructure>public transport; infrastructure>radio; infrastructure>recreation; infrastructure>road; infrastructure>school; infrastructure>secondary school; infrastructure>society; infrastructure>software; infrastructure>storm; infrastructure>sustainability; infrastructure>telecommunications; infrastructure>telephone; infrastructure>television; infrastructure>traffic light; infrastructure>trail; infrastructure>tram; infrastructure>transport; infrastructure>tunnel; infrastructure>university; infrastructure>water; infrastructure>weapon; infrastructure>vehicle; infrastructure>wheel; infrastructure>cooking; ingredient>law; ingredient>mixture; ingredient>recipe; inheritance>death; inheritance>debt; inheritance>god; inheritance>government; inheritance>individual; inheritance>myth; inheritance>northeast; inheritance>property; inheritance>sex; inheritance>turkey; initial>paragraph; initiative>referendum; injury>accident; injury>bruise; injury>skin; injury>suicide; injury>war; injury>violence; injury>wound; injustice>justice; ink>brush; ink>crystal; ink>design; ink>image; ink>liquid; ink>pen; ink>sustainability; ink>writing; innocence>child; innocence>crime; innocence>evil; innocence>experience; innocence>fiction; innocence>guilt; innocence>ignorance; innocence>sin; innocence>white; innocence>business; innovation>capitalism; innovation>carbon footprint; innovation>comfort; innovation>commerce; innovation>convenience; innovation>creativity; innovation>design; innovation>economics; innovation>education; innovation>efficiency; innovation>energy; innovation>engineering; innovation>globalization; innovation>government; innovation>hospital; innovation>idea; innovation>immigration; innovation>improvement; innovation>infrastructure; innovation>invention; innovation>manufacturing; innovation>market; innovation>material; innovation>productivity; innovation>regulation; innovation>research; innovation>society; innovation>technology; innovation>transportation; input>information; input>output; input>system; inquiry>analogy; inquiry>certainty; inquiry>curiosity; inquiry>diagnosis; inquiry>doubt; inquiry>hypothesis; inquiry>knowledge; inquiry>logic; inquiry>uncertainty; insect>agriculture; insect>animal; insect>ant; insect>bat; insect>bee; insect>bird; insect>blood; insect>butterfly; insect>carbon dioxide; insect>crab; insect>digestion; insect>evolution; insect>fat; insect>fly; insect>fruit; insect>genetics; insect>head; insect>honey; insect>human; insect>lung; insect>male; insect>mouth; insect>nutrition; insect>oxygen; insect>plant; insect>protein; insect>recycling; insect>robot; insect>sense; insect>silk; insect>species; insect>spider; insect>stomach; insect>wasp; insect>vein; insect>wheel; insecurity>risk; insecurity>security; insight>artificial intelligence; insight>brand; insight>cause; insight>consumer; insight>fluency; insight>marketing; insight>mind; insight>perception; insight>psychology; insight>sleep; insomnia>anxiety; insomnia>disease; insomnia>fear; insomnia>herb; insomnia>longevity; insomnia>pain; insomnia>sleep; insomnia>withdrawal; inspection>document; inspection>review; inspection>x-ray; inspector>captain; inspector>detective; inspector>fraud; inspector>police; inspector>police station; inspiration>invention; instinct>aggression; instinct>consciousness; instinct>learning; instinct>life; instinct>mammal; instinct>motivation; instinct>nest; instinct>psychology; instinct>sex; institute>research; institute>university; institutions>art; institutions>behaviour; institutions>business; institutions>capitalism; institutions>cooperation; institutions>corporation; institutions>country; institutions>court; institutions>culture; institutions>economics; institutions>education; institutions>factory; institutions>family; institutions>government; institutions>health care; institutions>hospital; institutions>individual; institutions>industry; institutions>institute; institutions>judge; institutions>language; institutions>law; institutions>marriage; institutions>medicine; institutions>money; institutions>nation; institutions>police; institutions>prison; institutions>religion; institutions>research; institutions>role; institutions>school; institutions>society; institutions>university; instructor>teacher; instructor>professor; instructor>teacher; instruments>tool; insult>rudeness; insurance>advertising; insurance>aircraft; insurance>airport; insurance>basketball; insurance>business; insurance>cash; insurance>community; insurance>contract; insurance>credit card; insurance>death; insurance>decade; insurance>disability; insurance>disaster; insurance>discrimination; insurance>earthquake; insurance>education; insurance>family; insurance>fire; insurance>funeral; insurance>gambling; insurance>gender; insurance>golf; insurance>horse; insurance>investment; insurance>loan; insurance>market; insurance>millennium; insurance>money; insurance>pension; insurance>politics; insurance>probability; insurance>profession; insurance>regulation; insurance>religion; insurance>retirement; insurance>revolution; insurance>saving; insurance>speculation; insurance>statistics; insurance>tax; insurance>terrorism; insurance>theft; insurance>tomato; insurance>unemployment; insurance>wage; insurance>wealth; insurance>weather; insurance>volcano; integrity>integrity; integrity>accuracy; integrity>bias; integrity>business; integrity>consciousness; integrity>doubt; integrity>honesty; integrity>hypocrisy; integrity>hypothesis; integrity>medicine; integrity>mind; integrity>politics; integrity>virtue; intellect>human; intellect>intellectual; intellect>intelligence; intellect>knowledge; intellect>logic; intellect>mind; intellect>profession; intellect>psychology; intellect>reality; intellect>truth; intellect>understanding; intellectual>art; intellectual>authority; intellectual>capitalism; intellectual>critic; intellectual>culture; intellectual>engineering; intellectual>essay; intellectual>evolution; intellectual>genetics; intellectual>intelligence; intellectual>journalist; intellectual>literacy; intellectual>literature; intellectual>medicine; intellectual>philosophy; intellectual>profession; intellectual>reason; intellectual>scholar; intellectual>socialism; intellectual>technology; intellectual>thought; intelligence>artificial intelligence; intelligence>bird; intelligence>communication; intelligence>definition; intelligence>dolphin; intelligence>elephant; intelligence>human; intelligence>knowledge; intelligence>learning; intelligence>mammal; intelligence>memory; intelligence>music; intelligence>parrot; intelligence>plan; intelligence>psychology; intelligence>reason; intelligence>science fiction; intelligence>scientist; intelligence>self-awareness; intelligence>understanding; intent>intention; intention>goal; intention>pyramid; interaction>feedback; interaction>gene; interaction>medication; interaction>medicine; interaction>physics; interaction>protein; interaction>science; interaction>statistics; interest>asset; interest>fee; interest>inflation; interest>money; interest>return; interest>spreadsheet; interest>theft; intervention>invasion; interview>question; intruder>intrusion; intrusion>erosion; intrusion>glass; intrusion>planet; intrusion>volcano; invasion>aggression; invasion>aircraft; invasion>archaeology; invasion>border; invasion>castle; invasion>city; invasion>coast; invasion>combat; invasion>communication; invasion>economics; invasion>entity; invasion>gold; invasion>government; invasion>infrastructure; invasion>navy; invasion>parachute; invasion>peace; invasion>philosophy; invasion>port; invasion>propaganda; invasion>radio; invasion>religion; invasion>river; invasion>silver; invasion>slavery; invasion>starvation; invasion>strategy; invasion>tank; invasion>technology; invasion>town; invasion>transportation; invasion>treaty; invasion>tribute; invasion>war; invasion>warrior; inventions>architecture; invention>art; invention>creativity; invention>design; invention>experiment; invention>flight; invention>machine; invention>parachute; invention>photography; invention>train; invention>invention; investigation>detective; investigation>disease; investigation>research; investigator>detective; investigator>inspector; investment>asset; investment>bank; investment>economics; investment>economy; investment>factory; investment>finance; investment>gambling; investment>inflation; investment>insurance; investment>money; investment>risk; investment>speculation; investment>stock; investor>antique; investor>art; investor>business; investor>commodity; investor>currency; investor>investment; investor>stock; iron>agriculture; iron>aluminium; iron>bean; iron>bread; iron>building; iron>carbon; iron>carbon dioxide; iron>carbon monoxide; iron>copper; iron>dna; iron>earth; iron>fish; iron>heart; iron>liver; iron>mammal; iron>metal; iron>mining; iron>oxygen; iron>paint; iron>road; iron>sand; iron>ship; iron>steel; iron>water; ironing>cotton; ironing>linen; ironing>silk; ironing>washing machine; ironing>wool; ironing>wrinkle; irony>coward; irony>genius; irony>hypocrisy; irony>legend; irony>love; irony>paradox; irritation>alcohol; irritation>biology; irritation>empathy; irritation>immune system; irritation>mammal; irritation>monkey; irritation>obesity; irritation>pain; irritation>perception; irritation>rash; irritation>tobacco; island>concrete; island>continent; island>coral; island>desert; island>geology; island>sand; island>tourism; island>water; island>water; isolation>solitude; issue>child; issue>journal; issue>magazine; issue>newspaper; jacket>baseball; jacket>chemistry; jacket>denim; jacket>fashion; jacket>garment; jacket>hunting; jacket>raincoat; jacket>sailor; jacket>scientist; jacket>sleeve; jacket>student; jacket>waist; jail>prison; january>february; january>march; january>oak; january>summer; january>winter; january>year; jar>bottle; jargon>bit; jargon>capitalism; jargon>philosopher; jargon>slang; jaw>bone; jaw>fish; jaw>tooth; jazz>arrangement; jazz>harmony; jazz>melody; jazz>piano; jazz>singer; jazz>slang; jazz>slavery; jazz>violin; jealousy>anger; jealousy>competition; jealousy>disgust; jealousy>emotion; jealousy>empathy; jealousy>envy; jealousy>feeling; jealousy>psychologist; jealousy>resentment; jealousy>self-esteem; jealousy>synonym; jeans>thought; jeans>copper; jeans>denim; jeans>teenager; jeans>trousers; jeans>turkey; jewel>jewellery; jewellery>archaeologist; jewellery>archaeology; jewellery>bone; jewellery>bracelet; jewellery>bronze; jewellery>coin; jewellery>copper; jewellery>culture; jewellery>diamond; jewellery>earring; jewellery>feather; jewellery>glass; jewellery>gold; jewellery>marriage; jewellery>metal; jewellery>necklace; jewellery>perfume; jewellery>plastic; jewellery>silver; jewellery>turkey; jewellery>wood; jogging>running; joint>bone; joint>elbow; joint>infection; joint>knee; joint>wrist; joke>clown; joke>comedy; joke>disability; joke>elephant; joke>humour; joke>irony; joke>laughter; joke>literature; joke>nonsense; joke>paradox; joke>poetry; joke>racist; joke>rhythm; joke>science; joke>sex; joke>smile; joke>stereotype; journal>diary; journal>journalism; journal>journalist; journal>magazine; journal>newspaper; journal>parliament; journalism>accuracy; journalism>democracy; journalism>disability; journalism>discrimination; journalism>newspaper; journalism>religion; journalism>truth; journalism>war; journalist>combat; journalist>critic; journalist>information; journalist>interview; journalist>journalism; journalist>microphone; journalist>murder; journalist>news; journalist>photography; journalist>research; journalist>turkey; journey>travel; joy>happiness; judge>black; judge>chancellor; judge>court; judge>jury; judge>law; judge>lawyer; judge>magistrate; judge>politics; judge>profession; judge>professor; judge>prosecutor; judge>red; judge>referee; judge>solicitor; jug>breast; jug>kettle; jug>prison; juice>kettle; juice>bacteria; juice>café; juice>fruit; juice>meat; juice>soft drink; juice>stroke; july>month; july>summer; july>winter; july>year; jump>assault; jumper>sweater; june>day; june>december; june>month; june>rose; june>summer; june>winter; june>year; jungle>rainforest; jungle>wilderness; junk food>chewing gum; junk food>dessert; junk food>sweet; junk food>fast food; junk food>fat; junk food>pizza; junk food>salt; junk food>slang; junk food>sugar; junk food>waste; junk>scrap; junk>waste; junk>woman; jury>abortion; jury>assault; jury>bribery; jury>competition; jury>court; jury>crime; jury>evidence; jury>judge; jury>justice; jury>murder; jury>prosecutor; jury>slavery; jury>terrorism; jury>trial; jury>verdict; justice>bias; justice>contract; justice>crime; justice>culture; justice>destiny; justice>disability; justice>discrimination; justice>gender; justice>generosity; justice>history; justice>human rights; justice>injustice; justice>judge; justice>jury; justice>law; justice>lawyer; justice>mercy; justice>nation; justice>need; justice>politician; justice>prison; justice>property; justice>punishment; justice>religion; justice>respect; justice>revenge; justice>slavery; justice>thrift; justice>wealth; justice>verdict; kangaroo>animal; kangaroo>carbon dioxide; kangaroo>extinction; kangaroo>mammal; kangaroo>mouse; kangaroo>predator; kangaroo>protein; kangaroo>reptile; kangaroo>species; kangaroo>windscreen; keeper>goalkeeper; kettle>salmon; kettle>whistle; key>chart; kick>foot; kick>knee; kid>child; kidney>adaptation; kidney>adjective; kidney>bean; kidney>bird; kidney>blood; kidney>carbon dioxide; kidney>conscience; kidney>cooking; kidney>fish; kidney>liver; kidney>mammal; kidney>protein; kidney>reptile; kidney>rib; kidney>water; killer>murderer; killing>death; kilo>kilogram; kilogram>carbon; kilogram>credit card; kilogram>density; kilogram>energy; kilogram>force; kilogram>gold; kilogram>gram; kilogram>lead; kilogram>litre; kilogram>metre; kilogram>millimetre; kilogram>ounce; kilogram>pressure; kilogram>uncertainty; kilogram>weight; kilometre>cycling; kilometre>length; kilometre>metre; kilometre>mile; kilometre>millimetre; kilometres>slang; kilometre>yard; kind>kindness; kindness>disposition; kindness>emotion; kindness>empathy; kindness>envy; kindness>generosity; kindness>love; kindness>sympathy; kindness>virtue; kingdom>realm; kiss>adolescent; kiss>affection; kiss>cholesterol; kiss>friendship; kiss>greeting; kiss>hug; kiss>lip; kiss>love; kiss>luck; kiss>muscle; kiss>peace; kiss>prayer; kiss>respect; kiss>temple; kiss>tongue; kiss>wedding; kit>collection; kit>component; kit>fox; kit>kitten; kit>rabbit; kitchen>aircraft; kitchen>apartment; kitchen>architect; kitchen>art; kitchen>basement; kitchen>bathroom; kitchen>brass; kitchen>bronze; kitchen>camping; kitchen>castle; kitchen>catering; kitchen>chimney; kitchen>climate; kitchen>coal; kitchen>cooking; kitchen>copper; kitchen>cupboard; kitchen>dining room; kitchen>dishwasher; kitchen>electricity; kitchen>factory; kitchen>fast food; kitchen>fire; kitchen>fireplace; kitchen>flour; kitchen>hall; kitchen>hotel; kitchen>industrialization; kitchen>iron; kitchen>laboratory; kitchen>laundry; kitchen>manion; kitchen>oven; kitchen>pottery; kitchen>pump; kitchen>railway; kitchen>restaurant; kitchen>rice; kitchen>ship; kitchen>sink; kitchen>slavery; kitchen>smoke; kitchen>society; kitchen>staircase; kitchen>steak; kitchen>triangle; kitchen>wood; kitchen>yacht; kite>aircraft; kite>art; kite>balloon; kite>beach; kite>cotton; kite>electricity; kite>force; kite>lightning; kite>linen; kite>observation; kite>paper; kite>recreation; kite>rope; kite>silk; kitten>birth; kitten>cat; kitten>eye; kitten>female; kitten>male; kitten>puppy; knee>baby; knee>bone; knee>joint; knee>surgery; knee>thigh; knife>blade; knife>bread; knife>bronze; knife>carbon; knife>copper; knife>cooking; knife>copper; knife>cutlery; knife>fish; knife>fork; knife>iron; knife>leather; knife>meat; knife>pillow; knife>plastic; knife>produce; knife>ritual; knife>rubber; knife>spoon; knife>steel; knife>surgery; knife>sword; knife>wood; knob>mountain; knot>chain; knot>climbing; knot>donkey; knot>joke; knot>puzzle; knot>rope; knot>strap; knowledge>belief; knowledge>certainty; knowledge>chair;

course>meat; main course>salad; main course>soup; main course>stomach; main course>vegetarian; majority>politics; male>ant; male>bee; male>bird; male>boy; male>female; male>flower; male>gent; male>genetics; male>gentleman; male>human; male>insect; male>iron; male>mammal; male>man; male>plant; male>reproduction; male>sex; male>worm; mammal>ant; mammal>bacteria; mammal>bat; mammal>bear; mammal>camel; mammal>cat; mammal>cattle; mammal>deer; mammal>dinosaur; mammal>dna; mammal>dog; mammal>donkey; mammal>elephant; mammal>giraffe; mammal>goat; mammal>hair; mammal>heart; mammal>horse; mammal>human; mammal>insect; mammal>intelligence; mammal>jaw; mammal>milk; mammal>mouse; mammal>neck; mammal>pig; mammal>polar bear; mammal>protein; mammal>rabbit; mammal>rat; mammal>reptile; mammal>sheep; mammal>skin; mammal>snake; mammal>species; mammal>stomach; mammal>whale; mammal>zebra; man>adult; man>beauty; man>bone; man>boy; man>costume; man>culture; man>dna; man>education; man>family; man>father; man>female; man>friend; man>genetics; man>human; man>illness; man>infrastructure; man>king; man>literature; man>male; man>mammal; man>muscle; man>shoulder; man>society; man>song; man>woman; management>business; management>college; management>commerce; management>corporation; management>finance; management>goal; management>innovation; management>leadership; management>marketing; management>organization; management>ownership; management>plan; management>planning; management>psychology; management>science; management>textbook; manager>management; mango>agriculture; mango>banana; mango>blood; mango>fibre; mango>flower; mango>frost; mango>fruit; mango>ice cream; mango>leaf; mango>pie; mango>roundabout; mango>salt; mango>seed; mango>silk; mango>supermarket; mango>tree; mango>wedding; mankind>human; mansion>castle; mansion>city; mansion>house; mansion>library; mansion>office; mansion>palace; mansion>railway; mansion>revolution; mansion>village; manual>hand; manufacturer>manufacturing; manufacturing>agriculture; manufacturing>aircraft; manufacturing>consumer; manufacturing>engineering; manufacturing>industry; manufacturing>infrastructure; manufacturing>machine; manufacturing>management; manufacturing>ownership; manufacturing>regulation; manufacturing>retailer; manufacturing>tool; map>border; map>dna; map>geography; map>measurement; map>rain; map>ratio; map>region; map>sign; map>space; map>sphere; map>survey; map>temperature; marathon>aspirin; marathon>immune system; marathon>liver; marathon>muscle; marathon>protein; march>autumn; march>day; march>friday; march>month; march>november; march>september; march>soil; march>sun; march>turkey; march>year; mark>football; market>auction; market>buyer; market>consumer; market>corporation; market>democracy; market>infrastructure; market>institution; market>money; market>monopoly; market>ownership; market>price; market>referee; market>seller; market>stock market; market>structure; market>subsidy; market>supermarket; market>system; market>tax; market>trade; market>workforce; marketing>advertising; marketing>brand; marketing>business; marketing>manufacturing; marketing>organization; marriage>community; marriage>contract; marriage>divorce; marriage>economics; marriage>emotion; marriage>family; marriage>fear; marriage>gender; marriage>human rights; marriage>husband; marriage>hypothesis; marriage>institution; marriage>mother; marriage>organization; marriage>parent; marriage>prejudice; marriage>priest; marriage>promise; marriage>referendum; marriage>right; marriage>sin; marriage>spouse; marriage>suicide; marriage>tribe; marriage>turkey; marriage>wedding; marriage>wife; marriage>vocation; mask>ballet; mask>baseball; mask>brass; mask>carnival; mask>cartoon; mask>ceremony; mask>community; mask>copper; mask>court; mask>devil; mask>disguise; mask>drama; mask>entertainment; mask>face; mask>folk; mask>god; mask>gold; mask>hero; mask>ice hockey; mask>leather; mask>museum; mask>performance; mask>procession; mask>prosecution; mask>protest; mask>ritual; mask>shield; mask>theatre; mask>torture; mask>trophy; mask>tv; mask>witness; massacre>disaster; massacre>sack; master>miss; masterpiece>painting; mat>bacteria; mat>bark; mat>bathroom; mat>building; mat>car; mat>carpet; mat>coconut; mat>commerce; mat>disc jockey; mat>floor; mat>furniture; mat>greeting; mat>kitchen; mat>pain; mat>pollution; mat>rubber; mat>sport; mat>straw; mat>structure; mat>surface; mat>towel; mat>type; mat>water; mat>vehicle; match>aircraft; match>chemistry; match>fire; match>firework; match>friction; match>glass; match>gun; match>lead; match>lighter; match>monopoly; match>nickname; match>paper; match>rope; match>rubber; match>slang; match>sugar; match>tool; match>wood; material>building; material>clothing; material>computer; material>construction; material>cotton; material>manufacturing; material>matter; material>steel; materialism>consciousness; materialism>energy; materialism>existence; materialism>force; materialism>institution; materialism>matter; materialism>mind; materialism>philosophy; materialism>reality; materialism>materialism; matter>atom; matter>chemistry; matter>density; matter>earth; matter>energy; matter>fluid; matter>formula; matter>gas; matter>lightning; matter>liquid; matter>materialism; matter>physics; matter>pressure; matter>science; matter>science fiction; matter>space; matter>telescope; matter>temperature; matter>time; matter>water; matter>wave; matter>volume; may>autumn; may>drum; may>month; may>november; may>summer; may>sunday; may>turkey; may>week; may>year; mayor>magistrate; mayor>officer; mayor>parliament; mayor>prime minister; mayor>referendum; meal>beach; meal>beer; meal>birthday; meal>breakfast; meal>cheese; meal>dessert; meal>dinner; meal>fish; meal>food; meal>forest; meal>fruit; meal>home; meal>lawn; meal>lunch; meal>main course; meal>nutrition; meal>park; meal>picnic; meal>restaurant; meal>salad; meal>sandwich; meal>supper; meal>tea; meal>wedding; meaning>reference; meaning>truth; measure>measurement; measurement>carbon; measurement>commerce; measurement>day; measurement>fraud; measurement>gram; measurement>hour; measurement>inch; measurement>kilogram; measurement>kilometre; measurement>law; measurement>length; measurement>light; measurement>metre; measurement>mile; measurement>month; measurement>ruler; measurement>science; measurement>second; measurement>spectrum; measurement>statistics; measurement>technology; measurement>temperature; measurement>time; measurement>ton; measurement>uncertainty; measurement>week; measurement>yard; measurement>year; meat>agriculture; meat>antibiotic; meat>bacteria; meat>barbecue; meat>beef; meat>body; meat>breed; meat>camel; meat>carbon dioxide; meat>cattle; meat>chicken; meat>cholesterol; meat>cooking; meat>crocodile; meat>deer; meat>disease; meat>dolphin; meat>evolution; meat>fat; meat>fish; meat>food; meat>game; meat>gun; meat>ham; meat>herb; meat>hygiene; meat>insect; meat>iron; meat>liver; meat>mammal; meat>muscle; meat>oak; meat>oxygen; meat>pain; meat>pork; meat>protein; meat>salt; meat>sandwich; meat>sausage; meat>sheep; meat>smoke; meat>species; meat>spice; meat>steak; meat>sugar; meat>supermarket; meat>whale; meat>wood; meat>zebra; mechanic>air conditioning; mechanic>brake; mechanic>customer; mechanic>electricity; mechanic>engine; mechanic>tank; mechanic>technician; mechanism>machine; medal>brass; medal>bronze; medal>coal; medal>copper; medal>glass; medal>gold; medal>iron; medal>lead; medal>paper; medal>plastic; medal>portrait; medal>relief; medal>sculpture; medal>silver; medal>soldier; medal>tin; medal>wood; medicine>amateur; medicine>antibiotic; medicine>aspirin; medicine>biology; medicine>clinic; medicine>diagnosis; medicine>dilemma; medicine>disease; medicine>ear; medicine>engineering; medicine>error; medicine>evolution; medicine>gene; medicine>genetics; medicine>health; medicine>health care; medicine>heart; medicine>honesty; medicine>illness; medicine>immune system; medicine>laboratory; medicine>literature; medicine>medication; medicine>nurse; medicine>philosophy; medicine>physics; medicine>poison; medicine>professional; medicine>psychology; medicine>pulse; medicine>side effect; medicine>snake; medicine>surgery; medicine>therapy; medicine>translation; medicine>tribe; medicine>truth; medicine>vaccination; medicine>vaccine; medicine>virus; medicine>x-ray; melody>composer; melody>harmony; melody>jazz; melody>lyrics; melody>rhythm; melody>song; member>bridge; member>club; membership>member; memorial>cross; memorial>fountain; memorial>money; memorial>monument; memorial>scholarship; memorial>statue; memorial>war; memory>knowledge; memory>learning; memory>phenomenon; memory>psychology; memory>recollection; memory>sleep; memory>university; mention>quote; menu>advertising; menu>chef; menu>fast food; menu>hospital; menu>restaurant; mercy>forgiveness; mercy>justice; message>communication; message>email; message>idea; message>information; message>language; message>radio; message>television; message>thought; metal>acid; metal>aluminium; metal>art; metal>bronze; metal>carbon; metal>chemistry; metal>commodity; metal>copper; metal>crystal; metal>currency; metal>density; metal>electricity; metal>gold; metal>heat; metal>iron; metal>lead; metal>painting; metal>silver; metal>steel; metaphor>analogy; metaphor>anger; metaphor>cliche; metaphor>description; metre>atom; metre>bar; metre>centimetre; metre>earth; metre>inch; metre>kilogram; metre>kilometre; metre>length; metre>light; metre>millimetre; metre>red; metre>second; metre>sphere; metre>yard; microphone>aircraft; microphone>computer; microphone>concert; microphone>insect; microphone>police; microphone>pressure; microphone>radio; microphone>sound; microphone>telephone; microphone>television; midday>noon; midnight>day; midnight>noon; midnight>season; midnight>sunrise; midnight>sunset; mile>emperor; mile>kilometre; mile>length; mile>metre; mile>province; mile>street; mile>yard; milk>acid; milk>agriculture; milk>bacteria; milk>beef; milk>bread; milk>butter; milk>camel; milk>cattle; milk>cheese; milk>cow; milk>cream; milk>digestion; milk>food; milk>goat; milk>gram; milk>honey; milk>horse; milk>human; milk>ice cream; milk>infant; milk>mammal; milk>nutrition; milk>pint; milk>polky; milk>protein; milk>sheep; milk>spinach; milk>supermarket; milk>turkey; milk>water; milk>vegetarian; milk>whale; milk>yogurt; millennium>analogy; millennium>calendar; millennium>century; millennium>decade; millimetre>inch; millimetre>length; millimetre>metre; mind>adaptation; mind>art; mind>artificial intelligence; mind>attention; mind>awareness; mind>biology; mind>body; mind>brain; mind>choice; mind>communication; mind>computer; mind>concept; mind>conscience; mind>consciousness; mind>conversation; mind>dialogue; mind>drama; mind>economics; mind>emotion; mind>empathy; mind>engineering; mind>evolution; mind>family; mind>fear; mind>feeling; mind>gene; mind>happiness; mind>hate; mind>human; mind>idea; mind>image; mind>imagination; mind>intelligence; mind>intention; mind>knowledge; mind>language; mind>learning; mind>life; mind>love; mind>machine; mind>materialism; mind>matter; mind>memory; mind>narrative; mind>perception; mind>philosopher; mind>philosophy; mind>pie; mind>psychology; mind>reality; mind>reason; mind>religion; mind>ritual; mind>science; mind>skull; mind>software; mind>soul; mind>spirit; mind>symbol; mind>taste; mind>therapist; mind>thought; mind>tool; mind>well-being; mind>video game; mind>yoga; mine>mining; miner>coal; miner>factory; mineral water>salt; mineral water>tourism; mining>agriculture; mining>aluminium; mining>coal; mining>commodity; mining>copper; mining>erosion; mining>factory; mining>geology; mining>gold; mining>laboratory; mining>lead; mining>metal; mining>silver; mining>tin; mining>tool; mining>tram; mining>weapon; mining>vein; minority>infancy; minority>majority; minority>population; minute>angle; minute>astronomy; minute>earth; minute>hour; minute>second; minute>time; miracle>coincidence; miracle>donkey; miracle>dream; miracle>earthquake; miracle>evidence; miracle>faith; miracle>god; miracle>history; miracle>philosophy; miracle>saint; miracle>science; mirror>angle; mirror>astronomy; mirror>laser; mirror>human; mirror>illusion; mirror>laser; mirror>mammal; mirror>mechanic; mirror>paint; mirror>photography; mirror>portrait; mirror>sphere; mirror>telescope; mirror>vase; mirror>x-ray; misery>pain; misery>suffering; misery>unhappiness; miss>mrs; miss>servant; missile>bomb; missile>engine; missile>explosive; missile>gun; missile>heat; missile>laser; missile>radiation; mist>air; mist>fog; mist>water; mist>weather; misunderstanding>understanding; mix>mixture; mixture>air; mixture>blood; mixture>chemistry; mixture>cloud; mixture>concrete; mixture>dust; mixture>fog; mixture>gas; mixture>gold; mixture>solution; mixture>sugar; mixture>water; mobile phone>email; mobile>mobile phone; mode>fashion; model>role model; model>system; momentum>explosion; momentum>heat; momentum>kilogram; momentum>light; momentum>plural; momentum>pressure; momentum>rocket; momentum>second; momentum>sound; momentum>star; momentum>wave; monday>angel; monday>heaven; monday>saturday; monday>sunday; monday>thursday; monday>tuesday; money>art; money>bank; money>banking; money>cash; money>century; money>cheque; money>commodity; money>copper; money>country; money>currency; money>debt; money>diamond; money>economics; money>exchange rate; money>gold; money>government; money>inflation; money>liberty; money>loan; money>monopoly; money>payment; money>receipt; money>recession; money>rice; money>silver; money>stock; money>tax; money>unemployment; monkey>human; monkey>species; monopoly>canal; monopoly>company; monopoly>competition; monopoly>famine; monopoly>industry; monopoly>law; monopoly>market; monopoly>regulation; monster>cattle; monster>colour; monster>devil; monster>dinosaur; monster>energy; monster>eye; monster>fish; monster>forehead; monster>genie; monster>goat; monster>legend; monster>lion; monster>mouse; monster>oxygen; monster>planet; monster>siren; monster>skull; month>april; month>august; month>autumn; month>calendar; month>day; month>december; month>february; month>inclination; month>january; month>july; month>june; month>march; month>may; month>november; month>october; month>rose; month>second; month>september; month>star; month>summer; month>sun; month>time; month>weekday; month>winter; month>year; monument>archaeologist; monument>building; monument>column; monument>memorial; monument>pyramid; monument>statue; monument>temple; monument>tomb; moonlight>daylight; moonlight>earth; moonlight>sun; moonlight>sunlight; morale>comfort; morale>courage; morale>duy; morale>fear; morale>motivation; morale>self-discipline; morale>willpower; mornings>afternoon; mornings>analogy; mornings>breakfast; mornings>dawn; mornings>day; mornings>evening; mornings>gene; mornings>midnight; mornings>newspaper; mornings>night; mornings>noon; mornings>sunrise; mortality>death; mortality>human; mosque>cathedral; mosque>clinic; mosque>column; mosque>dawn; mosque>gym; mosque>hazard; mosque>image; mosque>library; mosque>protest; mosque>pyramid; mosque>sunrise; mosque>sunset; mosque>symbol; mosque>vandalism; mosquito>adult; mosquito>animal; mosquito>bacteria; mosquito>bat; mosquito>carbon dioxide; mosquito>dawn; mosquito>disease; mosquito>fly; mosquito>head; mosquito>human; mosquito>immune system; mosquito>insect; mosquito>predator; mosquito>protein; mosquito>salmon; mosquito>sugar; mosquito>virus; mother>child; mother>emperor; mother>father; mother>human; mother>immune system; mother>mammal; mother>milk; mother>nutrition; mother>pregnancy; mother>stepmother; mother>wife; mother>woman; motivation>acceptance; motivation>addiction; motivation>curiosity; motivation>economics; motivation>family; motivation>feedback; motivation>food; motivation>friendship; motivation>game; motivation>goal; motivation>health; motivation>hunger; motivation>independence; motivation>love; motivation>money; motivation>observation; motivation>philosophy; motivation>psychologist; motivation>psychology; motivation>punishment; motivation>responsibility; motivation>safety; motivation>salary; motivation>saving; motivation>security; motivation>self-esteem; motivation>threat; motivation>tranquility; motivation>water; motive>motivation; motor>engine; mountain>agriculture; mountain>earth; mountain>erosion; mountain>hill; mountain>hobby; mountain>human; mountain>ice; mountain>landscape; mountain>mining; mountain>ocean; mountain>profession; mountain>river; mountain>snow; mountain>sport; mountain>tourism; mountain>volcano; mouse>animal; mouse>biology; mouse>cat;

mouse-disease; mouse>dog; mouse>earth; mouse>experiment; mouse>fox; mouse>gene; mouse>generation; mouse>ink; mouse>mammal; mouse>paper; mouse>pet; mouse>protein; mouse>psychology; mouse>rat; mouse>reptile; mouse>snake; mouse>species; mouse>stache>beard; mouse>stache>chin; mouse>stache>comb; mouse>stache>lip; mouse>stache>penicil; mouse>stache>scissors; move>immigration; movie>film; mud>brick; mud>concrete; mud>construction; mud>frog; mud>pig; mud>sand; mud>sol; mud>sun; mud>water; mud>worm; mug>coffee; mug>fluid; mug>pottery; mug>saucer; mug>tea; mum>mother; murder>animal; murder>assault; murder>corporation; murder>drug; murder>law; murder>precedent; murder>rape; murder>sin; murder>suicide; murder>war; murderer>murder; murderer>ancestor; muscle>bone; muscle>brain; muscle>cancer; muscle>cycling; muscle>density; muscle>dna; muscle>energy; muscle>fat; muscle>heart; muscle>infant; muscle>jaw; muscle>jogging; muscle>mammal; muscle>marathon; muscle>meat; muscle>motion; muscle>nerve; muscle>nerve; muscle>oxygen; muscle>protein; muscle>skeleton; muscle>stomach; muscle>tongue; museum>agriculture; museum>aircraft; museum>animal; museum>archaeology; museum>astronomy; museum>computer; museum>craft; museum>drawing; museum>geology; museum>glass; museum>history; museum>illustration; museum>invention; museum>library; museum>musician; museum>painting; museum>philosophy; museum>physics; museum>propaganda; museum>science; museum>sculpture; museum>tank; museum>technology; museum>weapon; museum>zoo; mushroom>anxiety; mushroom>cooking; mushroom>copper; mushroom>disease; mushroom>food; mushroom>immune system; mushroom>species; mushrooms>wool; music>addiction; music>archaeology; music>art; music>artificial intelligence; music>ballet; music>biology; music>choir; music>composer; music>computer; music>concert; music>cooperation; music>disc jockey; music>dissertation; music>emotion; music>entertainment; music>flute; music>globalization; music>guitar; music>harmony; music>intellect; music>jazz; music>language; music>lyrics; music>melody; music>memory; music>musician; music>opera; music>orchestra; music>performance; music>physics; music>piano; music>propaganda; music>psychology; music>radio; music>rhythm; music>singer; music>sound; music>speech; music>structure; music>television; music>time; music>university; music>violin; musical>music; musician>chapel; musician>composer; musician>jazz; musician>melody; musician>music; musician>poetry; musician>profession; musician>revolution; musician>singer; musician>singing; musician>society; mystery>secret; name>astronomy; name>dolphin; name>god; name>nickname; name>peace; name>science; name>slavery; name>spirit; name>war; nap>insomnia; nap>midday; nap>sleep; narrative>animation; narrative>communication; narrative>culture; narrative>data; narrative>description; narrative>dream; narrative>fiction; narrative>film; narrative>legend; narrative>literature; narrative>narrator; narrative>novel; narrative>openness; narrative>photography; narrative>poem; narrative>poetry; narrative>report; narrative>self; narrative>song; narrative>speech; narrative>television; narrative>theatre; narrative>validity; narrative>video; narrative>writing; nation>civilization; nation>community; nation>country; nation>culture; nation>government; nation>nationality; nation>society; nation>tribe; nationality>candidate; nationality>passport; nationality>politics; nationality>treaty; native speaker>first language; nature>adaptation; nature>air; nature>animal; nature>art; nature>atmosphere; nature>bacteria; nature>bay; nature>beauty; nature>biology; nature>bird; nature>bone; nature>civilization; nature>climate change; nature>cloud; nature>consciousness; nature>continent; nature>digestion; nature>dinosaur; nature>dna; nature>dust; nature>earth; nature>energy; nature>era; nature>evolution; nature>extinction; nature>fish; nature>fishing; nature>gas; nature>genetics; nature>habitat; nature>hill; nature>human; nature>hunting; nature>ice; nature>intrusion; nature>kilogram; nature>laboratory; nature>lake; nature>life; nature>lightning; nature>liquid; nature>mammal; nature>materialism; nature>matter; nature>mind; nature>mining; nature>mountain; nature>muscle; nature>observation; nature>ocean; nature>oxygen; nature>phenomenon; nature>photography; nature>physics; nature>planet; nature>plant; nature>poetry; nature>pollution; nature>pond; nature>recreation; nature>reproduction; nature>river; nature>science; nature>sea; nature>soil; nature>species; nature>star; nature>steam; nature>stream; nature>sun; nature>surface; nature>temperature; nature>tornado; nature>weather; nature>wilderness; nature>wildlife; nature>volcano; nature>zoo; navy>combat; navy>commander; navy>lake; navy>ocean; navy>port; navy>river; navy>sail; necessity>child; necessity>community; necessity>crime; necessity>law; necessity>organization; necessity>parent; neck>adjective; neck>body; neck>chin; neck>jaw; neck>pain; neck>throat; necklace>bracelet; necklace>bronze; necklace>chain; necklace>copper; necklace>coral; necklace>cross; necklace>diamond; necklace>gold; necklace>jewelry; necklace>laser; necklace>love; necklace>neck; necklace>shark; necklace>silver; necklace>tooth; necklace>vine; need>education; need>life; need>philosophy; need>politics; need>respect; need>self-esteem; neglect>abuse; neglect>negligence; neglect>self-esteem; neglect>carelessness; neglect>contract; neglect>harm; neglect>insurance; neglect>neglect; neglect>railway; neglect>train; negotiation>anger; negotiation>compromise; negotiation>contract; negotiation>conversation; negotiation>dialogue; negotiation>diplomacy; negotiation>disappointment; negotiation>emotion; negotiation>laboratory; negotiation>leadership; negotiation>pride; negotiation>sadness; negotiation>worry; neighbourhood>city; neighbourhood>community; neighbourhood>district; neighbourhood>fence; neighbourhood>household; neighbourhood>law; neighbourhood>security; neighbourhood>suburb; neighbourhood>town; neighbourhood>turkey; nerve>brain; nerve>muscle; nerve>pain; nerve>sense; nerve>skin; nerve>walking; nerves>nerve; nervousness>anxiety; nervousness>worry; nest>bird; nest>eagle; nest>fish; nest>grass; nest>habitat; nest>insect; nest>leaf; nest>life; nest>mammal; nest>reptile; nest>snake; nest>soil; nest>tree; nest>was; networking>network; news>consumer; news>information; news>mobile phone; news>opinion; news>radio; news>report; news>satellite; news>television; newsletter>club; newsletter>email; newsletter>interest; newsletter>marketing; newsletter>newspaper; newsletter>publication; newspaper>bias; newspaper>digital camera; newspaper>intellectual; newspaper>reporter; newspaper>weather forecast; nickname>ambiguity; nickname>ceremony; nickname>electrician; nickname>father; nickname>generation; nickname>genius; nickname>glasses; nickname>grandfather; nickname>home; nickname>intelligence; nickname>psychology; nickname>sir; nickname>surgeon; night>animal; night>carbon dioxide; night>day; night>earth; night>economy; night>fear; night>ghost; night>horizon; night>life; night>lighting; night>lighting; night>moonlight; night>nightclub; night>nightlife; night>planet; night>plant; night>police station; night>season; night>sleep; night>sun; night>time; night>water; nightclub>celebrity; nightclub>concert; nightclub>dance; nightclub>disc jockey; nightclub>disco; nightclub>nightlife; nightclub>techno; nightlife>adult; nightlife>concert; nightlife>entertainment; nightlife>murder; nightlife>music; nightlife>nightclub; nightlife>party; nightlife>restaurant; nightmare>anxiety; nightmare>brain; nightmare>dream; nightmare>fear; nightmare>fever; nightmare>harassment; nightmare>insomnia; nightmare>sadness; nightmare>sleep; nightmare>symptom; noise>data; noise>physics; noise>public transport; noise>radio; noise>silence; noise>sound; noise>television; noise>video; nomination>award; nomination>candidate; nomination>ceremony; nomination>debate; nomination>election; nomination>law; nomination>office; nonsense>contradiction; nonsense>grammar; nonsense>novelist; nonsense>poet; nonsense>poetry; nonsense>sense; nonsense>speech; nonsense>writing; noon>astronomy; noon>midnight; north>adjective; north>adverb; north>east; north>geography; north>map; north>noun; north>south; north>sun; north>west; northwest>southeast; nose>bat; nose>beak; nose>bird; nose>camel; nose>dog; nose>elephant; nose>mammal; nose>mouth; nose>nostril; nose>reptile; nostalgia>brain; nostalgia>happiness; nostalgia>music; nostalgia>sorrow; nostalgia>touch; nostril>bird; nostril>fish; nostril>human; nostril>mammal; nostril>nose; note>alphabet; note>music; note>musician; note>sound; notebook>drawing; notice>allegation; noun>adjective; noun>clause; noun>description; noun>determiner; noun>earth; noun>plural; noun>prefix; noun>preposition; noun>pronoun; noun>punctuation; noun>reference; noun>sense; noun>sex; noun>suffix; noun>verb; novel>adventure; novel>art; novel>bestseller; novels>child; novel>comic; novel>communication; novels>creativity; novels>dedication; novel>essay; novel>fantasy; novel>fiction; novel>gender; novel>globalization; novel>history; novel>individual; novel>industrialization; novel>invention; novel>joke; novel>literacy; novel>literature; novel>narrative; novel>newspaper; novel>psychology; novel>quest; novel>racism; novel>reality; novel>review; novel>science fiction; novel>sensibility; novel>virtual reality; novelist>novel; novelty>art; novelty>creativity; novelty>innovation; novelty>marketing; november>autumn; november>day; november>february; november>homelessness; november>january; november>march; november>may; november>month; november>saturday; november>sunday; november>war; november>winter; november>year; nuisance>agriculture; nuisance>contempt; nuisance>law; number>addition; numbers>full stop; number>measurement; number>pyramid; number>rectangle; number>uncountable; nutrition>agriculture; nutrition>atmosphere; nutrition>bean; nutrition>berry; nutrition>blood; nutrition>bread; nutrition>butter; nutrition>cancer; nutrition>carbon; nutrition>cheese; nutrition>chemical; nutrition>cholesterol; nutrition>confusion; nutrition>cooking; nutrition>copper; nutrition>diet; nutrition>digestion; nutrition>dna; nutrition>drought; nutrition>energy; nutrition>exercise; nutrition>experiment; nutrition>fast food; nutrition>fat; nutrition>flower; nutrition>food; nutrition>fruit; nutrition>garlic; nutrition>genetics; nutrition>grain; nutrition>grape; nutrition>herb; nutrition>human; nutrition>immune system; nutrition>iron; nutrition>junk food; nutrition>leaf; nutrition>life; nutrition>marathon; nutrition>meat; nutrition>metal; nutrition>milk; nutrition>obesity; nutrition>onion; nutrition>oxygen; nutrition>potato; nutrition>protein; nutrition>psychology; nutrition>pump; nutrition>rice; nutrition>root; nutrition>science; nutrition>seed; nutrition>soil; nutrition>spice; nutrition>starvation; nutrition>sugar; nutrition>sunlight; nutrition>tea; nutrition>teaching; nutrition>technology; nutrition>water; nutrition>vegetable; nutrition>wheat; nutrition>wine; nutrition>vitamin; oak>bark; oak>butterfly; oak>cattle; oak>cheese; oak>commander; oak>endurance; oak>euro; oak>flower; oak>fruit; oak>furniture; oak>goat; oak>leaf; oak>leather; oak>plant; oak>sheep; oak>ship; oak>species; oak>symbol; oak>tree; oak>wine; oak>virtue; oak>wood; obesity>appetite; obesity>cancer; obesity>famine; obesity>gene; obesity>globalization; obesity>junk food; obesity>medication; obesity>pregnancy; obesity>stroke; obesity>entity; object>goal; obligation>politics; obligation>tradition; observation>camera; observation>clock; observation>data; observation>equal; observation>experiment; observation>human; observation>hypothesis; observation>information; observation>knowledge; observation>measurement; observation>nature; observation>paradox; observation>phenomenon; observation>sense; observation>system; observation>taste; observation>telescope; observation>thermometer; observation>x-ray; observer>observation; obstacle>architecture; obstacle>basketball; obstacle>cycling; obstacle>electricity; obstacle>football; obstacle>idiom; obstacle>infrastructure; obstacle>majority; obstacle>parliament; obstacle>public transport; obstacle>skill; obstacle>tennis; obstacle>volleyball; occupation>career; occupation>employment; occupation>profession; occupation>vocation; ocean>animal; ocean>bay; ocean>climate; ocean>coast; ocean>continent; ocean>dolphin; ocean>earth; ocean>evolution; ocean>fish; ocean>global warming; ocean>habitat; ocean>ice; ocean>life; ocean>planet; ocean>plant; ocean>rain; ocean>sea; ocean>ship; ocean>species; ocean>water; ocean>weather; ocean>whale; ocean>wind; ocean>april; october>autumn; october>blindness; october>day; october>health; october>lung; october>month; october>pizza; october>republic; october>sausage; october>turkey; october>year; odds>gambling; odds>probability; odds>proposition; odds>ratio; odds>statistics; office>adjective; office>building; office>business; office>desk; office>employment; office>factory; office>fashion; office>library; office>official; office>organization; office>project; office>software; office>warehouse; officer>authority; officer>police officer; official>adjective; official>authority; official>bureaucracy; official>ceremony; official>election; official>school; official>signpost; official>title; official>war; offspring>adult; offspring>biology; offspring>bird; offspring>child; offspring>daughter; offspring>frog; offspring>parent; offspring>reproduction; offspring>son; oil>butter; oil>carbon; oil>heat; oil>light; oil>liquid; oil>protein; oil>autumn; oil>drought; oil>flower; oil>frost; oil>fruit; oil>garlic; oil>herb; oil>leaf; oil>lemon; oil>rabbit; oil>root; oil>soil; oil>species; oil>spice; oil>ton; oil>tree; oil>turkey; oil>umbrella; olive>weed; olive>vine; olive>wine; olive>winter; omelette>beef; omelette>butter; omelette>cheese; omelette>cholesterol; omelette>cream; omelette>fat; omelette>frying pan; omelette>garlic; omelette>ham; omelette>leek; omelette>lung; omelette>meat; omelette>milk; omelette>onion; omelette>pasta; omelette>pea; omelette>pork; omelette>potato; omelette>salt; omelette>tomato; omelette>vegetable; omission>argument; omission>lie; onion>bean; onion>carrot; onion>cat; onion>cattle; onion>cheese; onion>dog; onion>economist; onion>fat; onion>garlic; onion>gene; onion>spice; onion>vegetable; onion>vinegar; openness>community; opera>carival; opera>costume; opera>drama; opera>musician; opera>orchestra; opera>singing; opera>tradition; opera>tragedy; operation>surgery; opinion>argument; opinion>belief; opinion>business; opinion>committee; opinion>economics; opinion>emotion; opinion>fact; opinion>jury; opinion>knowledge; opinion>philosophy; opinion>psychology; opinion>understanding; opportunity>crisis; opposite>volleyball; optimism>cancer; optimism>evolution; optimism>health; optimism>idiom; optimism>intelligence; optimism>philosophy; optimism>psychology; optimism>stroke; optimist>optimism; orchestra>ballet; orchestra>cello; orchestra>choir; orchestra>committee; orchestra>composer; orchestra>court; orchestra>dancing; orchestra>flute; orchestra>melody; orchestra>musician; orchestra>opera; orchestra>piano; orchestra>trumpet; orchestra>violin; ordeal>cruelty; ordeal>difficulty; ordeal>problem; ordeal>suffering; ordeal>torture; order>sequence; organ>magazine; organ>newsletter; organization>bureaucracy; organization>committee; organization>communication; organization>competition; organization>corporation; organization>ecology; organization>economics; organization>entity; organization>goal; organization>government; organization>human; organization>jury; organization>leadership; organization>management; organization>parliament; organization>partnership; organization>psychology; organization>pyramid; organization>structure; organization>university; origin>ancestor; origin>birth; origin>river; origin>time; ornament>fashion; orphan>adoption; orphan>suicide; outbreak>disease; output>computer; output>data; output>economics; output>engineering; output>feedback; output>information; output>sequence; output>system; oven>bread; oven>brick; oven>cake; oven>casserole; oven>coal; oven>computer; oven>concrete; oven>cooking; oven>dessert; oven>electricity; oven>heating; oven>meat; oven>pizza; oven>pottery; oven>steel; overdraft>adverb; overdraft>bank; overdraft>contract; overdraft>debit; overdraft>interest; overdraft>preposition; owl>adaptation; owl>beak; owl>bird; owl>dawn; owl>dinosaur; owl>ecology; owl>feather; owl>fish; owl>insect; owl>mammal; owl>species; owl>traffic; owl>wisdom; owner>ownership; ownership>asset; ownership>body; ownership>building; ownership>business; ownership>capitalism; ownership>consideration; ownership>controversy; ownership>debt; ownership>exchange; ownership>gift; ownership>idea; ownership>individual; ownership>innovation; ownership>invention; ownership>law; ownership>manufacturing; ownership>mind; ownership>money; ownership>person; ownership>property; ownership>slavery; ownership>theft; oxygen>acid; oxygen>alcohol; oxygen>aluminium; oxygen>bacteria; oxygen>barbecue; oxygen>carbon; oxygen>carbon dioxide; oxygen>carbon monoxide; oxygen>centimetre; oxygen>climate change; oxygen>detective; oxygen>disease;

oxygen>dna; oxygen>earth; oxygen>explosion; oxygen>extinction; oxygen>fabric; oxygen>fat; oxygen>fire; oxygen>fuel; oxygen>gas; oxygen>immune system; oxygen>iron; oxygen>litre; oxygen>medicine; oxygen>ozone; oxygen>plastic; oxygen>protein; oxygen>rocket; oxygen>sand; oxygen>skeleton; oxygen>smog; oxygen>spider; oxygen>sport; oxygen>star; oxygen>steel; oxygen>sun; oxygen>tin; oxygen>water; oxygen>vein; oxygen>wood; ozone>aluminium; ozone>atom; ozone>carbon; ozone>carbon dioxide; ozone>climate change; ozone>concentration; ozone>earth; ozone>electricity; ozone>fruit; ozone>glass; ozone>gold; ozone>heart attack; ozone>immune system; ozone>iron; ozone>lead; ozone>lightning; ozone>liquid; ozone>metal; ozone>mining; ozone>oxygen; ozone>oxygen; ozone>salt; ozone>silver; ozone>water; ozone>vegetable; pace>peace; pack>backpack; pack>surname; pack>tourism; pact>contract; pact>treaty; page>web page; pain>anxiety; pain>cancer; pain>medication; pain>suffering; pain>toothache; pain>torque; pain>alcohol; paint>brush; paint>ink; paint>lead; paint>liquid; paint>milk; paint>oxygen; paint>sunshine; painter>painting; painting>art; painting>artist; painting>beauty; painting>brush; painting>concept; painting>copper; painting>craft; painting>design; painting>drawing; painting>essay; painting>face; painting>film; painting>glass; painting>illustration; painting>language; painting>leaf; painting>leather; painting>literature; painting>logo; painting>music; painting>nature; painting>oil; painting>paint; painting>paper; painting>pen; painting>philosophy; painting>photograph; painting>photography; painting>poetry; painting>politics; painting>portrait; painting>red; painting>rhythm; painting>sand; painting>solution; painting>straw; painting>surface; painting>symbol; painting>truth; painting>wall; painting>weather; painting>wood; painting>writing; pair>air; pair>cricket; pair>bear; pair>pressure; palace>castle; palace>chapel; palace>coconut; palace>hotel; palace>mansion; palace>museum; palace>parliament; palace>warehouse; pan>frying pan; pan>pancake; pan>prefix; pan>review; pancake>bacon; pancake>banana; pancake>breakfast; pancake>butter; pancake>cake; pancake>curry; pancake>fruit; pancake>frying pan; pancake>honey; pancake>jam; pancake>rice; pancake>synonym; pancake>yogurt; panel>jury; panic>anxiety; panic>architect; panic>cliff; panic>design; panic>emotion; panic>fear; panic>human; panic>marathon; panic>planning; panic>reason; panic>simulation; panic>symptom; pants>trousers; paper>art; paper>book; paper>cheque; paper>communication; paper>craft; paper>density; paper>diary; paper>drawing; paper>envelope; paper>grass; paper>handkerchief; paper>magazine; paper>newspaper; paper>notebook; paper>security; paper>straw; paper>wood; paper>writing; parachute>back; parachute>backpack; parachute>balloon; parachute>fair; parachute>landing; parachute>linen; parachute>probability; parachute>silk; parachute>weight; parade>carnival; parade>costume; parade>procession; parade>protest; paradigm>concept; paradigm>grammar; paradigm>photography; paradigm>physics; paradigm>science; paradigm>time; paradise>civilization; paradise>court; paradise>destiny; paradise>evil; paradise>evolution; paradise>garden; paradise>god; paradise>happiness; paradise>heaven; paradise>hell; paradise>park; paradise>peace; paradise>prosperity; paradise>space; paradise>time; paradise>yard; paradox>common sense; paradox>contradiction; paradox>dilemma; paradox>irony; paradox>language; paradox>logic; paradox>philosopher; paradox>surgery; paradox>validity; paragraph>email; paragraph>idea; paragraph>initial; paragraph>writing; parallel>astronomy; parcel>mail; parent>adoptive; parent>adoption; parent>ancestor; parent>bird; parent>birth; parent>child; parent>family; parent>father; parent>gene; parent>generation; parent>infant; parent>male; parent>mother; parent>offspring; parent>pregnancy; parent>protein; parent>reproduction; parent>sibling; parent>verb; park>car park; park>government; park>grass; park>insect; park>landscape; park>mansion; park>picnic; park>playground; park>recreation; park>shade; park>turkey; park>woodland; parking>board game; parking>fee; parking>house; parking>road; parking>vehicle; parliament>appeal; parliament>citizen; parliament>democracy; parliament>finance; parliament>government; parliament>justice; parliament>legislation; parliament>prime minister; parliament>tax; parrot>animal; parrot>bacteria; parrot>beak; parrot>bird; parrot>competition; parrot>dinosaur; parrot>evolution; parrot>flower; parrot>food; parrot>fruit; parrot>hunting; parrot>pet; parrot>poison; parrot>predator; parrot>rat; parrot>seed; parrot>species; parrot>tongue; parrot>manufacturer; particle>atom; particle>lead; particle>carbon dioxide; particle>crowd; particle>dust; particle>friction; particle>gas; particle>liquid; particle>matter; particle>nature; particle>people; particle>sand; particle>sphere; particle>star; particle>structure; particle>volume; partner>friend; partner>husband; partner>partnership; partner>wife; partnership>alliance; partnership>contract; partnership>corporation; partnership>corruption; partnership>education; partnership>entity; partnership>government; partnership>interest; partnership>monopoly; partnership>organization; partnership>school; party>anniversary; party>balloon; party>banana; party>birthday; party>business; party>cake; party>conversation; party>dancing; party>dessert; party>dinner; party>disc jockey; party>disco; party>drink; party>election; party>film; party>food; party>friendship; party>hospitality; party>main course; party>mask; party>music; party>noise; party>opera; party>recreation; party>restaurant; party>sandwich; party>school; party>swimming pool; party>tea; party>techno; party>wedding; party>wine; passage>cave; passenger>bus; passenger>railway; passenger>ship; passenger>vehicle; passport>diplomacy; passport>government; passport>nationality; passport>receipt; passport>refugee; passport>travel; passport>treaty; password>backup; password>face; password>graphics; password>image; password>memory; password>mobile phone; password>word; pasta>cereal; pasta>chef; pasta>cholesterol; pasta>cooking; pasta>export; pasta>flour; pasta>ham; pasta>machine; pasta>sausage; pasta>hobby; pastry>bakery; pastry>biscuit; pastry>bread; pastry>butter; pastry>chocolate; pastry>cream; pastry>flour; pastry>milk; pastry>pasta; pastry>pie; pastry>sugar; patch>garden; patience>envy; patience>humility; patience>insect; patience>kindness; patience>pride; patience>time; patient>clinic; patient>dignity; patient>health care; patient>hospital; patient>human rights; patient>illness; patient>medication; patient>surgeon; patient>therapy; patient>treatment; pattern>carpet; pattern>column; pattern>crack; pattern>crystal; pattern>drawing; pattern>physics; pattern>pineapple; pattern>reflection; pattern>tree; pattern>wave; pause>leisure; paw>bear; paw>cat; paw>dog; paw>fox; paw>friction; paw>mammal; paw>rabbit; paw>toe; pay>payment; pay>salary; pay>wage; payment>business; payment>cash; payment>cheque; payment>coin; payment>commerce; payment>credit card; payment>debit card; payment>money; payment>receipt; payment>stock; payment>trade; pc>postcard; pc>weather forecast; pea>bean; pea>butter; pea>climate; pea>famine; pea>fruit; pea>genetics; pea>noun; pea>plant; pea>plural; pea>protein; pea>salt; pea>seed; pea>snack; pea>soup; pea>tree; pea>turkey; pea>vegetable; pea>vine; pea>vitamin; peace>aggression; peace>cooperation; peace>diplomacy; peace>economics; peace>geography; peace>history; peace>hostility; peace>knowledge; peace>psychology; peace>respect; peace>silence; peace>strategy; peace>tranquility; peace>war; peace>violence; peach>acid; peach>cherry; peach>flower; peach>fruit; peach>leaf; peach>psych; peach>plant; peach>protein; peach>tree; peak>rush hour; peak>summit; peanut>beef; peanut>bird; peanut>cancer; peanut>cholesterol; peanut>cookie; peanut>cotton; peanut>flower; peanut>fruit; peanut>leaf; peanut>paint; peanut>plant; peanut>plastic; peanut>rabbit; peanut>seed; peanut>spinach; pear>apple; pear>banana; pear>family; pear>flower; pear>furniture; pear>jam; pear>juice; pear>leaf; pear>olive; pear>plant; pear>rice; pear>species; pear>tobacco; pear>winter; pear>wood; peasant>farmer; peasant>literacy; peasant>slavery; pedestrian>obesity; pedestrian>public transport; pedestrian>road; pedestrian>running; pedestrian>traffic; pedestrian>trail; pedestrian>walking; pedestrian>vehicle; pedestrian>wheelchair; peer pressure>adolescent; peer pressure>alcohol; peer pressure>leadership; peer pressure>meeting; peer pressure>presentation; peer pressure>risk; peer pressure>tobacco; pen>ball; pen>brass; pen>drawing; pen>illustration; pen>ink; pen>inventor; pen>paper; pen>pencil; pen>status symbol; pen>stet; pen>writing; penalty>punishment; penny>tax; pence>penny; pencil>chemistry; pencil>drawing; pencil>lead; pencil>leather; pencil>pen; pencil>ruler; pencil>wood; pencil>writing; penguin>animal; penguin>bird; penguin>evolution; penguin>fish; penguin>habitat; penguin>iceberg; penguin>species; penguin>tail; penguin>wing; penny>commodity; penny>devil; penny>dollar; penny>euro; penny>silver; penny>asset; pension>government; pension>insurance; pension>investment; pension>lottery; pension>pensioner; pension>retirement; pension>stock; pension>tax; pensioner>pension; pensioner>retirement; pensioner>student; people>citizen; people>nation; people>nationality; people>person; people>republic; people>socialism; people>tribe; percentage>concentration; percentage>ratio; percentage>road; perception>brain; perception>ear; perception>ecology; perception>food; perception>hypothesis; perception>illusion; perception>information; perception>learning; perception>memory; perception>motivation; perception>paradigm; perception>psychology; perception>science; perception>sense; perception>simulation; perception>sound; perception>taste; perception>tongue; perfection>architect; perfection>architecture; perfection>artist; perfection>beauty; perfection>biology; perfection>chemistry; perfection>circle; perfection>civilization; perfection>concept; perfection>cooperation; perfection>creativity; perfection>crystal; perfection>education; perfection>existence; perfection>formula; perfection>god; perfection>grammar; perfection>harmony; perfection>health; perfection>heaven; perfection>idea; perfection>intellect; perfection>literature; perfection>matter; perfection>medicine; perfection>nature; perfection>number; perfection>painting; perfection>paradise; perfection>paradox; perfection>philosopher; perfection>philosophy; perfection>physics; perfection>plural; perfection>poet; perfection>poetry; perfection>proverb; perfection>ratio; perfection>reason; perfection>religion; perfection>science; perfection>sculpture; perfection>shape; perfection>side; perfection>skill; perfection>society; perfection>sphere; perfection>spirit; perfection>structure; perfection>sum; perfection>superlative; perfection>technology; perfection>temple; perfection>virtue; performance>actor; performance>audience; performance>baller; performance>baseball; performance>comedian; performance>concert; performance>dance; performance>music; performance>opera; performance>rehearsal; performance>singing; performance>theatre; perfume>aluminium; perfume>apple; perfume>bark; perfume>bulb; perfume>chemistry; perfume>cherry; perfume>cola; perfume>corporation; perfume>dirty; perfume>flower; perfume>fruit; perfume>heat; perfume>herb; perfume>honey; perfume>leaf; perfume>lemon; perfume>light; perfume>make-up; perfume>oxygen; perfume>pine; perfume>plant; perfume>root; perfume>rose; perfume>science; perfume>seed; perfume>shampoo; perfume>spice; perfume>strawberry; perfume>tobacco; perfume>tomato; perfume>trade; perfume>wood; period>full stop; person>abortion; person>consciousness; person>estate; person>human; person>individual; person>law; person>liberty; person>nation; person>people; person>philosophy; person>slavery; person>slavery; person>family; person>self; person>employment; person>advertising; person>belief; person>communication; person>deception; person>deception; person>faith; person>imagination; person>intention; person>logic; person>motivation; person>party; person>presentation; person>propaganda; person>torture; person>tradition; pet>animal; pet>ant; pet>bird; pet>cat; pet>chocolate; pet>crab; pet>crocodile; pet>deer; pet>dog; pet>feather; pet>frog; pet>fur; pet>goat; pet>horse; pet>leopard; pet>lion; pet>monkey; pet>parrot; pet>rabbit; pet>sheep; pet>snake; pet>spider; pet>tiger; pharmacist>biology; pharmacist>chemist; pharmacist>chemist; pharmacist>chemistry; pharmacist>disease; pharmacist>economics; pharmacist>health; pharmacist>health care; pharmacist>medication; pharmacist>nutrition; pharmacist>patient; pharmacist>pharmacy; pharmacist>physics; pharmacist>wage; pharmacy>chemistry; pharmacy>clinic; pharmacy>copper; pharmacy>health; pharmacy>health care; pharmacy>hospital; pharmacy>lead; pharmacy>magazine; pharmacy>medication; pharmacy>nutrition; pharmacy>partnership; pharmacy>pharmacist; pharmacy>retailer; pharmacy>shampoo; pharmacy>supermarket; pharmacy>surgery; pharmacy>symbol; phenomenon>energy; phenomenon>experience; phenomenon>matter; phenomenon>observation; phenomenon>occurrence; phenomenon>philosophy; phenomenon>physics; phenomenon>theory; philosopher>argument; philosopher>concept; philosopher>human; philosopher>knowledge; philosopher>logic; philosopher>person; philosopher>philosophy; philosopher>proposition; philosopher>society; philosopher>argument; philosophy>art; philosophy>beauty; philosophy>belief; philosophy>body; philosophy>debate; philosophy>democracy; philosophy>dialogue; philosophy>economics; philosophy>essence; philosophy>existence; philosophy>faith; philosophy>god; philosophy>government; philosophy>health; philosophy>humility; philosophy>hypothesis; philosophy>integrity; philosophy>justice; philosophy>language; philosophy>law; philosophy>literature; philosophy>logic; philosophy>longevity; philosophy>lyrics; philosophy>materialism; philosophy>mind; philosophy>music; philosophy>nature; philosophy>number; philosophy>proposition; philosophy>proverb; philosophy>psychology; philosophy>reality; philosophy>reason; philosophy>reasoning; philosophy>theory; philosophy>time; philosophy>truth; philosophy>validity; philosophy>world; philosophy>yoga; phone>telephone; photo>photograph; photograph>acid; photograph>camera; photograph>dust; photograph>image; photograph>light; photograph>photography; photographer>advertising; photographer>amateur; photographer>landscape; photographer>photography; photographer>portrait; photograph>art; photograph>beauty; photograph>camera; photograph>computer; photograph>digital camera; photograph>gain; photograph>hobby; photograph>image; photograph>light; photograph>photocopy; photograph>photograph; photograph>photographer; photograph>professional; photograph>science; photograph>television; photograph>thermometer; photograph>tourism; photograph>video; phrasal verb>cliché; phrasal verb>collocation; phrasal verb>idiom; phrasal verb>particle; phrasal verb>phrase; phrasal verb>preposition; phrasal verb>verb; phrase>clause; phrase>word; physics>archaeology; physics>astronomy; physics>atom; physics>biology; physics>bridge; physics>chemistry; physics>computer; physics>curriculum; physics>earth; physics>electricity; physics>energy; physics>engineering; physics>experiment; physics>film; physics>force; physics>geology; physics>heat; physics>industrialization; physics>laser; physics>light; physics>lightning; physics>liquid; physics>matter; physics>nature; physics>phenomenon; physics>philosophy; physics>prediction; physics>research; physics>science; physics>society; physics>sound; physics>space; physics>technology; physics>television; physics>temperature; physics>theory; physics>time; physics>uncertainty; physics>water; physics>video game; piano>cd; piano>clutch; piano>composer; piano>jazz; piano>mp3 player; piano>performance; piano>rehearsal; piano>steel; piano>television; picnic>barbecue; picnic>earth; picnic>meal; picnic>rush hour; picnic>finger; picnic>soft drink; picture>image; pie>army; pie>basket; pie>beef; pie>pottery; pie>biscuit; pie>box; pie>bread; pie>butter; pie>cake; pie>chicken; pie>flour; pie>honey; pie>horse; pie>ice cream; pie>leaf; pie>mushroom; pie>pizza; pie>pottery; pie>sea; pie>steak; pie>vegetable; pie>wheat; piece>coin; piece>sandwich; piece>unit; pig>animal; pig>art; pig>bacon; pig>extinction; pig>hair; pig>hunting; pig>idiom; pig>leather; pig>literature; pig>mammal; pig>metaphor; pig>porc; pig>relic; pig>tooth; pillow>back; pillow>bed; pillow>chair; pillow>cloth; pillow>cotton; pillow>cushion; pillow>down; pillow>dust; pillow>duvet; pillow>feather; pillow>knee; pillow>laundry; pillow>neck; pillow>silks; pillow>sleep; pillow>television; pin>brass; pin>copper; pin>plastic; pin>steel; pin>wire; pine>bark; pine>bird; pine>butterfly; pine>desert; pine>goat; pine>goat; pine>leaf; pine>park; pine>plant; pine>seed; pine>sole; pine>species; pine>tea; pine>timber; pine>tree; pineapple>bat; pineapple>cancer; pineapple>cherry; pineapple>digestion; pink>advertising; pink>aluminium; pink>beauty; pink>blue; pink>cartoon; pink>clothing; pink>corporation; pink>dawn; pink>girl; pink>globalization; pink>green; pink>hat; pink>health; pink>innocence; pink>love; pink>newspaper; pink>people; pink>pig; pink>prosecution; pink>purple; pink>red; pink>scarf; pink>slang; pink>socialism; pink>sollicitor;

psychology>experiment; psychology>explanation; psychology>happiness; psychology>information; psychology>interview; psychology>knowledge; psychology>laboratory; psychology>language; psychology>learning; psychology>medicine; psychology>memory; psychology>motivation; psychology>myth; psychology>pain; psychology>paradigm; psychology>perception; psychology>persuasion; psychology>philosophy; psychology>physics; psychology>pleasure; psychology>psychiatrist; psychology>psychologist; psychology>questionnaire; psychology>reasoning; psychology>school; psychology>stereotype; psychology>symbol; psychology>teaching; psychology>technology; psychology>thought; psychology>tool; pub>beer; pub>century; pub>dna; pub>freezer; pub>intellectual; pub>landlord; pub>nightclub; pub>pie; pub>pump; pub>stable; pub>tournament; public transport>airline; public transport>bus; public transport>canal; public transport>carbon dioxide; public transport>cd player; public transport>fare; public transport>ferry; public transport>passenger; public transport>pollution; public transport>revenue; public transport>rush hour; public transport>subsidy; public transport>traffic jam; publication>magazine; publication>newspaper; publicity>advertising; publicity>book; publicity>celebrity; publicity>employment; publicity>film; publicity>marketing; pudding>brand; pudding>butter; pudding>cereal; pudding>dessert; pudding>flour; pudding>milk; puddings>oven; puddings>rice; pudding>saucepan; pudding>sugar; pullover>gymnastics; pullover>sweater; pulse>blood; pulse>bone; pulse>elbow; pulse>heart; pulse>knee; pulse>light; pulse>medicine; pulse>neck; pulse>wrist; pump>air conditioning; pump>energy; pump>gas; pump>liquid; pump>pressure; punctuation>alphabet; punctuation>drama; punctuation>full stop; punctuation>semicolon; punctuation>time; punctuation>usage; punctuation>writing; punishment>authority; punishment>child; punishment>cooperation; punishment>crime; punishment>criminal; punishment>law; punishment>liberty; punishment>pain; punishment>parent; punishment>prison; punishment>revenge; punishment>society; punishment>teacher; pupil>alcohol; pupil>cat; pupil>dog; pupil>evolution; pupil>fox; pupil>goat; pupil>horse; pupil>plural; pupil>sheep; puppy>birth; puppy>dog; puppy>eye; puppy>kitten; purity>vice; purple>air; purple>blood; purple>blue; purple>capitalism; purple>emperor; purple>red; purple>rose; purple>silk; purple>soundtrack; purple>star; purple>sugar; purple>tennis; purple>wool; purpose>intention; purpose>boxing; purse>handbag; purse>wallet; push>force; puzzle>game; puzzle>inquiry; puzzle>pattern; puzzle>problem; puzzle>research; puzzle>toy; puzzle>verb; pyramid>basketball; pyramid>brick; pyramid>millennium; pyramid>pottery; pyramid>temple; pyramid>tomb; pyramid>turkey; pyramid>volleyball; qualification>education; qualification>examination; qualification>tournament; quantity>circle; quantity>density; quantity>distance; quantity>energy; quantity>gender; quantity>heat; quantity>noun; quantity>person; quantity>pressure; quantity>ratio; quantity>time; quantity>volume; quarrel>arrow; query>question; quest>fantasy; quest>friendship; quest>hero; quest>literature; quest>temptation; question marks>diagnosis; question marks>exclamation mark; question marks>full stop; question marks>punctuation; question marks>semicolon; question marks>university; question>answer; question>concept; question>debate; question>doubt; question>exam; question>examination; question>grammar; question>information; question>inquiry; question>logic; question>philosophy; question>problem; question>proposition; question>question mark; question>quiz; question>research; question>theory; question>truth; question>verb; questionnaire>question; questionnaire>research; questionnaire>statistics; quiet>silence; quiz>blog; quiz>game; quiz>radio; quiz>television; quotation>author; quotation>blog; quotation>cliché; quotation>email; quotation>film; quotation>painting; quotation>proverb; quotation>punctuation; quote>quotation; rabbit>animal; rabbit>cartoon; rabbit>cat; rabbit>desert; rabbit>disease; rabbit>dog; rabbit>forest; rabbit>fur; rabbit>gas; rabbit>gun; rabbit>luck; rabbit>mammal; rabbit>predator; rabbit>pregnancy; rabbit>prolein; rabbit>sheep; rabbit>species; rabbit>vitamin; rabbit>woodland; rabbit>wool; racism>biology; racism>culture; racism>discrimination; racism>dislike; racism>education; racism>folk; racism>health care; racism>history; racism>human rights; racism>jazz; racism>nation; racism>philosophy; racism>politician; racism>prejudice; racism>statistics; racism>stereotype; racism>synonym; racism>violence; racism>xenophobia; racist>racism; radiation>atom; radiation>cancer; radiation>energy; radiation>light; radiation>physics; radiation>red; radiation>radiation; radiation>sun; radiation>thermometer; radiation>x-ray; radio>atom; radio>computer; radio>dvd; radio>electronics; radio>energy; radio>hobby; radio>horizon; radio>information; radio>invention; radio>investment; radio>light; radio>microphone; radio>mobile phone; radio>music; radio>regulation; radio>silk; radio>technology; radio>telecommunications; radio>television; radio>violin; radio>x-ray; raid>terrorist; rail>curtain; rail>agriculture; rain>atmosphere; rain>climate; rain>cloud; rain>continent; rain>desert; rain>drought; rain>flood; rain>global warming; rain>hail; rain>iron; rain>ocean; rain>parachute; rain>plant; rain>rainbow; rain>raincoat; rain>smoke; rain>snow; rain>snowfall; rain>storm; rain>summer; rain>thunder; rain>thunderstorm; rain>tornado; rain>umbrella; rain>water; rain>weather; rain>wings>aeroplane; rainbow>angle; rainbow>blue; rainbow>cloud; rainbow>experiment; rainbow>fountain; rainbow>green; rainbow>helicopter; rainbow>horizon; rainbow>laser; rainbow>light; rainbow>red; rainbow>sunlight; rainbow>waterfall; rainbow>wave; rainbow>yellow; raincoat>rain; rainforest>acre; rainforest>adaptation; rainforest>aluminium; rainforest>bacteria; rainforest>bat; rainforest>bird; rainforest>branch; rainforest>butterfly; rainforest>carbon dioxide; rainforest>cloud; rainforest>coast; rainforest>earh; rainforest>earth; rainforest>ecology; rainforest>extinction; rainforest>forest; rainforest>iron; rainforest>jungle; rainforest>leaf; rainforest>leopard; rainforest>lung; rainforest>mammal; rainforest>medicine; rainforest>monkey; rainforest>oxygen; rainforest>rain; rainforest>reptile; rainforest>river; rainforest>snake; rainforest>species; rainforest>sunlight; rainforest>tree; rainforest>turkey; rainforest>vegetation; rainforest>vine; rainforest>volcano; rank>hierarchy; rape>anger; rape>blackmail; rape>blood; rape>consent; rape>family; rape>friend; rape>human rights; rape>marriage; rape>police; rape>secondary school; rape>suicide; rape>suicide; rape>war; rape>virgin; rash>blister; rash>bruise; rash>friction; rash>heat; rash>irritation; rash>pregnancy; rash>sun; rash>vaccine; rat>animal; rat>bean; rat>brain; rat>breed; rat>cat; rat>crime; rat>disease; rat>drug; rat>ecology; rat>experiment; rat>genetics; rat>health; rat>heart; rat>intelligence; rat>kidney; rat>live; rat>mammal; rat>mouse; rat>noun; rat>psychology; rat>science fiction; rat>species; rat>suburb; rat>verb; rate>exchange rate; rate>evaluation; ratio>slope; ratio>television; razor>barber; razor>blade; razor>bread; razor>bronze; razor>cutlery; razor>tool; reality>astronomy; reality>consciousness; reality>culture; reality>disposition; reality>dream; reality>energy; reality>essence; reality>evolution; reality>existence; reality>fact; reality>fantasy; reality>fiction; reality>film; reality>future; reality>illusion; reality>imagination; reality>jargon; reality>knowledge; reality>language; reality>lie; reality>life; reality>matter; reality>measurement; reality>mind; reality>momentum; reality>nature; reality>necessity; reality>novel; reality>observation; reality>phenomenon; reality>philosophy; reality>physics; reality>politics; reality>present; reality>quantity; reality>reason; reality>religion; reality>science fiction; reality>space; reality>theory; reality>thought; reality>time; reality>truth; reality>virtual reality; reality>virtue; realm>empire; reason>argument; reason>art; reason>artificial intelligence; reason>behaviour; reason>belief; reason>calculation; reason>cause; reason>conscience; reason>consciousness; reason>economics; reason>facts; reason>faith; reason>fantasy; reason>feeling; reason>friendship; reason>head; reason>heart; reason>history; reason>human; reason>imagination; reason>inquiry; reason>institution; reason>intellect; reason>knowledge; reason>language; reason>law; reason>logic; reason>mind; reason>nature; reason>philosopher; reason>philosophy; reason>probability; reason>psychology; reason>reality; reason>religion; reason>revelation; reason>science; reason>space; reason>symbol; reason>theory; reason>thought; reason>time; reason>tradition; reason>truth; reason>wisdom; reasoning>reason; rebel>rebellion; rebellion>authority; rebellion>behaviour; rebellion>government; rebellion>insurgent; rebellion>revolution; rebellion>terrorism; receipt>euro; receipt>payment; receipt>tax; reception>popularity; reception>receipt; reception>receptionist; receptionist>business; receptionist>coffee; receptionist>company; receptionist>employee; receptionist>greeting; receptionist>interview; receptionist>mail; receptionist>office; receptionist>organization; receptionist>secretary; receptionist>tea; receptionist>telephone; recession>merger; recession>productivity; recipe>bay; recipe>food; recognition>award; record>document; record>recording; recording>data; recording>writing; recovery>cure; recreation>amusement; recreation>beach; recreation>god; recreation>recreation; recreation>entertainment; recreation>fun; recreation>happiness; recreation>leisure; recreation>park; recreation>pleasure; recreation>seminar; recreation>sleep; recreation>tourism; recruit>recruitment; recruitment>advertising; recruitment>company; recruitment>employer; recruitment>employment; recruitment>knowledge; recruitment>literacy; recruitment>organization; recruitment>reference; recruitment>skill; rectangle>angle; rectangle>area; rectangle>butterfly; rectangle>circle; rectangle>green; rectangle>length; rectangle>square; rectangle>wire; recycling>aluminium; recycling>architect; recycling>chemist; recycling>computer; recycling>demand; recycling>economics; recycling>economist; recycling>electronics; recycling>energy; recycling>environmentalist; recycling>factory; recycling>finance; recycling>glass; recycling>gold; recycling>iron; recycling>law; recycling>lead; recycling>market; recycling>material; recycling>metal; recycling>mining; recycling>paper; recycling>plastic; recycling>resource; recycling>steel; recycling>sustainability; recycling>timber; recycling>warehouse; recycling>waste; recycling>wool; red>aggression; red>anger; red>autumn; red>beauty; red>blood; red>blue; red>cherry; red>courage; red>drum; red>dvd; red>fire; red>food; red>force; red>green; red>happiness; red>hate; red>heat; red>laser; red>love; red>medicine; red>night; red>oak; red>pottery; red>risk; red>rose; red>socialism; red>soft drink; red>south; red>sport; red>star; red>strawberry; red>sugar; red>sun; red>sunrise; red>temperature; red>time; red>tomato; red>turkey; red>war; red>well-being; red>violin; red>yellow; redevelopment>carbon footprint; referee>cricket; referee>female; referee>ice hockey; referee>sport; referee>volleyball; reference>art; reference>committee; reference>diary; reference>dictionary; reference>energy; reference>god; reference>invention; reference>knowledge; reference>library; reference>meeting; reference>negotiation; reference>noun; reference>prefix; reference>project; reference>pronoun; reference>referee; reference>referendum; reference>telephone; reference>validity; reference>word; referendum>alcohol; referendum>constitution; referendum>currency; referendum>election; referendum>euro; referendum>gerund; referendum>independence; referendum>initiative; referendum>law; referendum>majority; referendum>propaganda; referendum>republic; referendum>unity; referendum>vote; reform>hyphen; reform>revolution; reform>spelling; refuge>safety; refugee>anxiety; refugee>arrest; refugee>climate change; refugee>country; refugee>exile; refugee>government; refugee>human rights; refugee>male; refugee>nationality; refugee>passport; refugee>poverty; refugee>risk; refugee>suicide; refugee>turkey; refugee>war; refugee>violence; regime>geography; regime>measurement; region>atmosphere; region>climate; region>continent; region>county; region>culture; region>earth; region>earthquake; region>ecology; region>economics; region>exploration; region>geography; region>geology; region>human; region>ocean; region>politics; region>poverty; region>tourism; region>water; registration>register; regulation>contract; regulation>economics; regulation>employment; regulation>government; regulation>industry; regulation>information; regulation>law; regulation>monopoly; regulation>policy; regulation>pollution; regulation>price; regulation>society; regulation>wage; rehearsal>performance; reign>death; relation>diplomacy; relaxation>recreation; relevance>contradiction; relevance>description; relevance>distraction; relevance>economist; relevance>famine; relevance>intent; relevance>poverty; relief>bronze; relief>earth; relief>sun; religion>art; religion>belief; religion>culture; religion>dance; religion>education; religion>evolution; religion>experiment; religion>faith; religion>family; religion>festival; religion>funeral; religion>god; religion>government; religion>hospital; religion>law; religion>music; religion>philosophy; religion>politics; religion>prayer; religion>priest; religion>revelation; religion>ritual; religion>sacrifice; religion>science; religion>symbol; religion>temple; religion>terrorism; religion>theory; religion>worship; relish>cooking; relish>fruit; relish>garlic; relish>jam; relish>pear; relish>sauce; relish>vegetable; remains>body; remains>skeleton; remark>comment; remedy>cure; remedy>education; remedy>therapy; remorse>empathy; remorse>fear; remorse>goddess; remorse>resentment; remorse>resentment; remote control>dvd; remote control>electronics; remote control>microphone; remote control>robot; remote control>television; remote control>tv; renovation>engineering; renovation>planning; renovation>repair; reply>answer; reply>question; report>presentation; reporter>journalist; representation>contract; reproduction>adult; reproduction>analogy; reproduction>animal; reproduction>bacteria; reproduction>bee; reproduction>bird; reproduction>evolution; reproduction>female; reproduction>fish; reproduction>genetics; reproduction>human; reproduction>life; reproduction>lottery; reproduction>male; reproduction>plant; reproduction>rabbit; reproduction>reptile; reproduction>seed; reproduction>sex; reproduction>shark; reproduction>virus; reptile>bird; reptile>crocodyl; reptile>digestion; reptile>dinosaur; reptile>fish; reptile>heart; reptile>kidney; reptile>leather; reptile>lion; reptile>lung; reptile>mammal; reptile>oxygen; reptile>snake; reptile>common sense; reptile>constitution; reptile>couple; reptile>democracy; reptile>independence; reptile>president; reptile>prime minister; reputation>assault; reputation>asset; reputation>auction; reputation>behaviour; reputation>belief; reputation>brand; reputation>business; reputation>candidate; reputation>citizen; reputation>community; reputation>company; reputation>competitor; reputation>consumer; reputation>cooperation; reputation>corporation; reputation>culture; reputation>customer; reputation>deception; reputation>definition; reputation>education; reputation>employee; reputation>evaluation; reputation>evolution; reputation>friendship; reputation>globalization; reputation>gossip; reputation>government; reputation>headline; reputation>honour; reputation>industry; reputation>interaction; reputation>investor; reputation>journalism; reputation>leadership; reputation>management; reputation>news; reputation>opinion; reputation>organization; reputation>person; reputation>phenomenon; reputation>potential; reputation>risk; reputation>role; reputation>science; reputation>social networking; reputation>stock market; reputation>sum; reputation>wealth; request>question; requirement>illusion; requirement>implementation; rescue>ambulance; rescue>court; rescue>helicopter; rescue>horse; rescue>injury; rescue>life; rescue>patient; rescue>police; rescue>prosecutor; rescue>tool; rescue>training; rescue>vehicle; rescue>wilderness; rescue>analysis; rescue>art; rescue>corporation; rescue>credibility; rescue>curiosity; rescue>dissertation; rescue>evidence; rescue>experiment; rescue>history; rescue>hypothesis; rescue>information; rescue>integrity; rescue>interpretation; rescue>knowledge; rescue>medicine; rescue>nature; rescue>scholar; rescue>science; rescue>theory; researcher>research; researcher>science; researcher>scientist; resemblance>similarity; resentment>anger; resentment>contempt; resentment>discrimination; resentment>envy; resentment>hatred; resentment>injustice; resentment>jealousy; resentment>prejudice; resentment>remorse; resentment>revenge; resentment>status; reserve>park; residence>home; residence>house; resident>patient; resignation>election; resignation>inheritance; resistance>friction; resort>beach; resort>coast; resort>entertainment; resort>golf; resort>hotel; resort>nightclub; resort>pub; resort>recreation; resort>restaurant; resort>skiing; resort>soft drink; resort>swimming pool; resort>tourism; resource>air; resource>benefit; resource>biology; resource>competition; resource>computer; resource>cost; resource>ecology; resource>economics; resource>fish; resource>infrastructure; resource>interest; resource>leadership; resource>management; resource>prosperity; resource>reproduction; resource>risk; resource>scarcity; resource>sustainability; resource>wage;

resource>water; resource>wealth; respect>affection; respect>disrespect; respect>entity; respect>person; respect>pronoun; respect>rudeness; response>answer; response>output; responsibility>blame; responsibility>duty; responsibility>obligation; rest>leg; rest>leisure; rest>sleep; restaurant>business; restaurant>catering; restaurant>chef; restaurant>customer; restaurant>disability; restaurant>drink; restaurant>fast food; restaurant>food; restaurant>hygiene; restaurant>lunch; restaurant>menu; restaurant>mess; restaurant>pub; restaurant>review; restaurant>steak; restaurant>waiter; restraint>brake; restraint>self-control; restriction>regulation; result>accuracy; result>advantage; result>calculation; result>change; result>competition; result>confrontation; result>credibility; result>democracy; result>disadvantage; result>economics; result>election; result>experiment; result>gain; result>game; result>information; result>injury; result>justice; result>lottery; result>phenomenon; result>relevance; result>research; result>science; result>sequence; result>statistics; result>war; result>victory; result>vote; result>consumer; retail>department store; retail>download; retail>manufacturing; retail>marketing; retail>menu; retail>mp3 player; retail>pedestrian; retail>price; retail>recreation; retail>reputation; retail>roof; retail>shopping; retail>supermarket; retail>telephone; retail>trade; retail>workforce; retailer>retail; retirement>disability; retirement>employment; retirement>golf; retirement>hobby; retirement>inflation; retirement>investment; retirement>pension; retirement>researcher; retirement>sailing; retirement>saving; retirement>sport; retirement>stock market; retirement>tourism; retirement>volunteer; retreat>therapy; return>election; rewards>award; revelation>angel; revelation>authority; revelation>good; revelation>materialism; revelation>miracle; revelation>physics; revelation>religion; revelation>scholar; revelation>sin; revenge>dignity; revenge>forgiveness; revenge>generation; revenge>honour; revenge>murder; revenge>turkey; revenge>war; revenue>asset; revenue>bank; revenue>barber; revenue>business; revenue>cash; revenue>corporation; revenue>currency; revenue>expense; revenue>expenses; revenue>manufacturing; revenue>stock; review>book; review>car; review>computer; review>essay; review>film; review>socialist; review>video game; revolution>capitalism; revolution>coup; revolution>culture; revolution>democracy; revolution>discrimination; revolution>economy; revolution>force; revolution>harvest; revolution>history; revolution>philosophy; revolution>pump; revolution>rebellion; revolution>recession; revolution>reform; revolution>regime; revolution>religion; revolution>riot; revolution>society; revolution>technology; revolution>theory; revolution>war; rhyme>poem; rhyme>rhythm; rhyme>song; rhyme>syllable; rhyme>synonym; rhythm>dance; rhythm>drum; rhythm>jazz; rhythm>pattern; rhythm>stroke; rhythm>time; rib>bone; rib>chest; rib>fish; rib>frog; rib>heart; rib>lung; rib>neck; rib>reptile; rib>snake; rib>x-ray; ribbon>cloth; ribbon>ink; ribbon>metal; ribbon>plastic; ribbon>silk; ribbon>symbol; ribbon>velvet; rice>basket; rice>carbon dioxide; rice>people; rice>disease; rice>pressure; rice>rat; rice>seed; rice>straw; rice>volume; riches>wealth; richness>wealth; riot>authority; riot>harvest; riot>hockey; riot>imprisonment; riot>celebrity; riot>police; riot>property; riot>protest; riot>rebellion; riot>religion; riot>revolution; riot>sport; riot>violence; risk>sunrise; risk>adventure; risk>ambiguity; risk>anxiety; risk>asset; risk>certainty; risk>crisis; risk>disaster; risk>emergency; risk>finance; risk>fraud; risk>gambling; risk>hazard; risk>insurance; risk>luck; risk>probability; risk>professional; risk>speculation; risk>threat; risk>uncertainty; risk>workplace; ritual>carnival; ritual>ceremony; ritual>community; ritual>dance; ritual>drinking; ritual>food; ritual>music; ritual>psychology; ritual>religion; ritual>singing; ritual>tradition; ritual>worship; rival>competition; rivalry>rival; river>bridge; river>canal; river>cave; river>cereal; river>drought; river>ferry; river>flood; river>lake; river>litre; river>mammal; river>ocean; river>planet; river>pressure; river>sailing; river>sand; river>sea; river>stream; river>tide; river>tunnel; river>water; river>waterfall; river>wool; road>brick; road>bridge; road>bus; road>city; road>cliff; road>concrete; road>copper; road>clay; road>economics; road>erosion; road>ferry; road>lane; road>law; road>lead; road>motorway; road>mountain; road>pedestrian; road>person; road>planning; road>roundabout; road>sand; road>sea; road>slope; road>society; road>statistics; road>stream; road>street; road>traffic; road>traffic light; road>trail; road>travel; road>tree; road>walking; road>waste; road>vegetation; road>vehicle; road>village; robbery>blackmail; robbery>burglary; robbery>crime; robbery>intention; robbery>mobile phone; robbery>theft; robbery>weapon; robot>artificial intelligence; robot>disability; robot>electronics; robot>laboratory; robot>legend; robot>pharmacist; robot>planet; robot>technology; robot>theatre; robot>virtual reality; robot>volcano; rock>jewellery; rocket>acre; rocket>aircraft; rocket>bomb; rocket>firework; rocket>flight; rocket>fluid; rocket>force; rocket>fuel; rocket>helicopter; rocket>landing; rocket>legend; rocket>missile; rocket>missile; rocket>oxygen; rocket>parachute; rocket>petrol; rocket>rescue; rocket>satellite; rocket>weapon; rocket>vehicle; role>ambiguity; role>behaviour; role>economics; role>electrician; role>genetics; role>philosophy; role>punishment; role>right; role>shopkeeper; role>society; roll>role; roof>aluminium; roof>arch; roof>banana; roof>building; roof>cathedral; roof>ceiling; roof>construction; roof>copper; roof>electricity; roof>heat; roof>house; roof>lead; roof>legislation; roof>material; roof>rain; roof>snow; roof>stadium; roof>steel; roof>straw; roof>sunlight; roof>timber; roof>weather; roof>wind; room>bathroom; room>bedroom; room>box; room>door; room>kitchen; room>staircase; room>suburb; room>wall; roommate>apartment; roommate>loneliness; roommate>privacy; root>bacteria; root>carrot; root>cherry; root>iron; root>mango; root>plant; root>potato; root>strawberry; root>temple; root>tree; root>water; rope>anchor; rope>chain; rope>construction; rope>cotton; rope>fibre; rope>grass; rope>knot; rope>leather; rope>linen; rope>sail; rope>silk; rope>straw; rope>wool; rose>alcohol; rose>bird; rose>chocolate; rose>coast; rose>erosion; rose>flower; rose>herb; rose>insect; rose>jam; rose>leaf; rose>plant; rose>root; rose>sand; round>circle; round>sphere; roundabout>bicycle; roundabout>motorist; roundabout>pedestrian; roundabout>traffic light; roundabout>tram; roundabout>van; row>controversy; rubbish>waste; rudeness>cough; rudeness>crime; rudeness>dignity; rudeness>gender; rudeness>insult; rudeness>library; rudeness>mobile phone; rudeness>noise; rudeness>politeness; rudeness>religion; rudeness>snob; rug>carpet; rugby>swimming pool; rule>government; rule>law; rule>ruler; ruler>lead; ruler>waist; ruling>rule; run>running; run>stream; runner>running; running>endurance; running>jogging; running>marathon; running>mud; running>oxygen; running>speed; running>walking; runway>aircraft; runway>brick; runway>concrete; runway>coral; runway>density; runway>distance; runway>grass; runway>ice; runway>landing; runway>salt; runway>sand; runway>snow; runway>soil; runway>weather; runway>wind; rush hour>construction; rush hour>fast food; rush hour>festival; rush hour>lunchtime; rush hour>public transport; rush hour>restaurant; rush hour>traffic; rush hour>train; rush hour>weather; rush hour>worship; sack>bag; sack>bed; sacrifice>civilization; sacrifice>death; sacrifice>god; sacrifice>metaphor; sacrifice>murder; sacrifice>sun; sacrifice>worship; saddle>camel; saddle>cattle; saddle>horse; saddle>pressure; saddle>status symbol; saddle>sword; sadness>anger; sadness>disgust; sadness>empathy; sadness>fear; sadness>happiness; sadness>pupil; safety>accident; safety>aircraft; safety>awareness; safety>bicycle; safety>boat; safety>child; safety>error; safety>guarantee; safety>harm; safety>insurance; safety>regulation; safety>risk; safety>roundabout; safety>security; safety>traffic light; safety>training; sail>kite; sail>machine; sail>recreation; sail>sailing; sail>wing; sail>yacht; sailing>crew; sailing>fishing; sailing>geography; sailing>history; sailing>port; sailing>recreation; sailing>sail; sailing>sailor; sailing>weather; sailing>wind; sailing>windsurfing; sailing>wing; sailing>yacht; sailor>air conditioning; sailor>electrician; sailor>iceberg; sailor>navy; sailor>nurse; sailor>sail; sailor>sailing; sailor>belief; sailor>god; sailor>heaven; sailor>icon; sailor>revelation; sailor>virtue; sailor>worship; salad>appetite; salad>bacon; salad>beef; salad>carrot; salad>casserole; salad>cheese; salad>cucumber; salad>dessert; salad>fast food; salad>fish; salad>fruit; salad>herb; salad>lettuce; salad>main course; salad>meal; salad>meat; salad>milk; salad>mushroom; salad>onion; salad>pasta; salad>salmon; salad>sauce; salad>spice; salad>spinach; salad>steak; salad>supermarket; salad>tomato; salad>tuna; salad>vegetable; salad>vinegar; salad>yogurt; salary>beer; salary>corporation; salary>office; salary>overtime; salary>partnership; salary>profession; salary>salt; salary>slavery; salary>soldier; salary>wage; salary>village; salmon>cholesterol; salmon>protein; salmon>species; salt>animal; salt>fire; salt>iron; salt>mining; salt>plastic; salt>pregnancy; salt>rice; salt>salary; salt>soap; salt>stroke; salt>sunlight; salt>taste; salt>water; sand>agriculture; sand>beach; sand>brick; sand>erosion; sand>floor; sand>flower; sand>iron; sand>material; sand>paint; sand>soil; sandal>ankle; sandal>boot; sandal>fashion; sandal>foot; sandal>leather; sandal>rope; sandal>rubber; sandal>shoe; sandal>therapy; sandal>toe; sandal>trekking; sandal>wood; sandal>yoga; sandwich>bread; sandwich>cheese; sandwich>ham; sandwich>meat; sandwich>picnic; sandwich>sauce; satellite>circle; satellite>climate; satellite>earth; satellite>human; satellite>image; satellite>inclination; satellite>landing; satellite>shadow; satellite>sun; satellite>telecommunications; satellite>turkey; saturday>day; saturday>friday; saturday>harvest; saturday>hour; saturday>purple; saturday>slang; saturday>sun; saturday>sunday; saturday>sweets; saturday>thursday; saturday>week; saturday>weekend; sauce>beef; sauce>cooking; sauce>dessert; sauce>fruit; sauce>ham; sauce>liquid; sauce>pork; sauce>potato; sauce>salad; sauce>tomato; sauce>vegetable; saucer>cat; saucer>coffee; saucer>spoon; saucer>tea; sausage>barbecue; sausage>beef; sausage>beer; sausage>blood; sausage>bread; sausage>breakfast; sausage>butcher; sausage>carrot; sausage>casserole; sausage>comedy; sausage>cooking; sausage>deer; sausage>fat; sausage>fate; sausage>hierarchy; sausage>industry; sausage>kangaroo; sausage>leek; sausage>lemon; sausage>lunch; sausage>onion; sausage>plastic; sausage>poet; sausage>pork; sausage>potato; sausage>pudding; sausage>ratio; sausage>salmon; sausage>sandwich; sausage>spice; sausage>stomach; sausage>taste; sausage>turkey; sausage>vegetable; sausage>vegetarian; sausage>wine; sausage>vinegar; saving>bank; saving>cost; saving>income; saving>interest; saving>investment; saving>money; saving>pension; saving>recession; savings>saving; saying> cliché; saying>idiom; scar>accident; scar>bone; scar>chest; scar>disease; scar>fat; scar>hernia; scar>injury; scar>muscle; scar>pregnancy; scar>shoulder; scar>skin; scar>surgery; scar>wound; scar>extinction; scar>resource; scar>society; scar>species; scar>colour; scar>fashion; scar>garment; scar>religion; scar>waist; scarf>wool; scarf>ballerina; scarf>composer; scarf>opera; scarf>scenery; scarf>breakfast; scarf>classroom; scarf>college; scarf>education; scarf>gang; scarf>gym; scarf>health care; scarf>institution; scarf>leisure; scarf>library; scarf>lunch; scarf>mosque; scarf>office; scarf>primary school; scarf>secondary school; scarf>self-esteem; scarf>soldier; scarf>student; scarf>teacher; scarf>toddler; scarf>university; scarf>vandalism; scarf>child>child; scarf>schooling; scarf>school; science fiction>archaeology; science fiction>artificial intelligence; science fiction>chemistry; science fiction>computer; science fiction>disaster; science fiction>economics; science fiction>electricity; science fiction>email; science fiction>fantasy; science fiction>fiction; science fiction>film; science fiction>future; science fiction>history; science fiction>imagination; science fiction>innovation; science fiction>narrative; science fiction>novel; science fiction>optimism; science fiction>physics; science fiction>psychology; science fiction>satellite; science fiction>science; science fiction>technology; science fiction>video game; science>accuracy; science>astronomy; science>biology; science>calculator; science>cancer; science>certainty; science>chemistry; science>civilization; science>concept; science>dna; science>electronics; science>energy; science>engineering; science>entertainment; science>evolution; science>fact; science>formula; science>geology; science>hygiene; science>hypothesis; science>knowledge; science>literature; science>logic; science>measurement; science>medicine; science>mobile phone; science>nature; science>observation; science>phenomenon; science>philosophy; science>physics; science>poetry; science>policy; science>politician; science>potential; science>psychology; science>religion; science>research; science>science fiction; science>scientist; science>society; science>species; science>statistics; science>technology; science>telecommunications; science>television; science>theory; science>truth; science>vaccination; science>watch; scientist>archaeologist; scientist>artificial intelligence; scientist>astronomy; scientist>biology; scientist>blood; scientist>career; scientist>chemist; scientist>chemistry; scientist>computer; scientist>data; scientist>disease; scientist>ecology; scientist>economist; scientist>electronics; scientist>engineer; scientist>experiment; scientist>genetics; scientist>heat; scientist>human; scientist>knowledge; scientist>laboratory; scientist>light; scientist>matter; scientist>medicine; scientist>mind; scientist>music; scientist>musician; scientist>nature; scientist>number; scientist>nurse; scientist>observation; scientist>perception; scientist>philosophy; scientist>physics; scientist>planet; scientist>priest; scientist>probability; scientist>profession; scientist>psychologist; scientist>reality; scientist>science; scientist>technology; scientist>thought; scientist>world; scissors>barber; scissors>blade; scissors>branch; scissors>bronze; scissors>child; scissors>cloth; scissors>fingernail; scissors>food; scissors>grass; scissors>hair; scissors>hairdresser; scissors>iron; scissors>metal; scissors>moustache; scissors>paper; scissors>pillow; scissors>plastic; scissors>rope; scissors>rubber; scissors>surgery; scissors>toenail; scissors>wire; scissors>wool; score>pottery; scrap>death; scrap>engine; scrap>injury; scrap>machinery; scrap>waste; scratch>ice hockey; scratch>money; scratch>video game; screen>cable; screen>television; sculpture>aluminium; sculpture>archaeology; sculpture>architecture; sculpture>bicycle; sculpture>bronze; sculpture>concrete; sculpture>emperor; sculpture>glass; sculpture>gold; sculpture>jewellery; sculpture>mask; sculpture>material; sculpture>medal; sculpture>metal; sculpture>museum; sculpture>oak; sculpture>paint; sculpture>pottery; sculpture>proverb; sculpture>relief; sculpture>silver; sculpture>statue; sculpture>steel; sculpture>stone; sculpture>temperature; sculpture>theft; sculpture>wood; sea>aircraft; sea>art; sea>bacteria; sea>carbon dioxide; sea>coal; sea>cod; sea>commodity; sea>composer; sea>copper; sea>coral; sea>environmentalist; sea>fish; sea>friction; sea>gold; sea>infrastructure; sea>iron; sea>lake; sea>lead; sea>literature; sea>ocean; sea>oil; sea>opera; sea>oxygen; sea>penguin; sea>poetry; sea>port; sea>protagonist; sea>reptile; sea>river; sea>robot; sea>sailing; sea>salmon; sea>sand; sea>science fiction; sea>silver; sea>skeleton; sea>species; sea>sun; sea>surfing; sea>symbol; sea>theatre; sea>tide; sea>transport; sea>tuna; sea>war; sea>whale; sea>virus; season>astronomy; season>autumn; season>calendar; season>climate; season>data; season>daylight; season>definition; season>diagram; season>earth; season>ecology; season>month; season>noon; season>ocean; season>rain; season>snow; season>spring; season>summer; season>sun; season>sunlight; season>tornado; season>weather; season>wind; season>winter; season>year; seat>bench; seat>chair; seat>saddle; seat>throw; second>clock; second>day; second>earth; second>hour; second>minute; second>time; secondary school>college; secondary school>geography; secondary school>history; secondary school>institution; secondary school>primary school; secondary school>science; secondary school>university; secretary>economics; secretary>receptionist; secretary>university; sector>area; sector>region; sector>advertisement; security>burglar; security>information; security>insecurity; security>intruder; security>police; security>risk; security>safety; security>threat; security>>window; seed>animal; seed>ant; seed>apple; seed>bean; seed>bird; seed>cereal; seed>cherry; seed>coconut; seed>cooking; seed>cotton; seed>digestion; seed>fish; seed>flower; seed>forest; seed>fruit; seed>light; seed>mammal; seed>oak; seed>pea; seed>peach; seed>peanut; seed>pine; seed>plant; seed>potato; seed>protein; seed>rain; seed>reproduction; seed>reptile; seed>snow; seed>spice; selection>evolution; selection>genetics; self>consciousness; self>individual; self>sin; self>assurance>self-confidence; self-

awareness>artificial intelligence; self-awareness>confidence; self-awareness>consciousness; self-awareness>elephant; self-awareness>intelligence; self-awareness>person; self-awareness>reality; self-awareness>reasoning; self-awareness>science fiction; self-awareness>scientist; self-awareness>soul; self-confidence>confidence; self-confidence>psychology; self-confidence>self-esteem; self-confidence>vanity; self-control>emotion; self-control>psychology; self-esteem>acceptance; self-esteem>animal; self-esteem>biology; self-esteem>chemistry; self-esteem>creativity; self-esteem>education; self-esteem>emotion; self-esteem>experiment; self-esteem>feeling; self-esteem>happiness; self-esteem>love; self-esteem>measurement; self-esteem>perception; self-esteem>person; self-esteem>pride; self-esteem>psychology; self-esteem>self-awareness; self-esteem>self-confidence; self-esteem>sense; self-esteem>shame; self-esteem>shyness; self-esteem>teaching; self-esteem>economy; selfishness>empathy; selfishness>generosity; selfishness>philosophy; selfishness>psychology; selfishness>religion; self-respect>self-esteem; semicolon>clause; semicolon>comma; semicolon>exclamation mark; semicolon>full stop; semicolon>punctuation; semicolon>question mark; semicolon>word; seminar>debate; seminar>lecture; seminar>university; sensation>sense; sense>attention; sense>bat; sense>bee; sense>bird; sense>blindness; sense>blood; sense>communication; sense>dolphin; sense>drug; sense>illusion; sense>insect; sense>light; sense>pain; sense>perception; sense>pressure; sense>psychologist; sense>reptile; sense>shark; sense>skin; sense>snake; sense>sound; sense>sweet; sense>taste; sense>throat; sense>lime; sense>tongue; sense>touch; sensibility>emotion; sentiment>emotion; sentiments>feeling; september>autumn; september>day; september>month; september>school; september>year; sequence>bit; sequence>uncountable; series>episode; series>sequence; series>serial; series>species; set>gang; set>jargon; set>onion; set>potato; set>setting; set>tennis; setback>problem; setting>classroom; sewing>archaeology; sewing>bone; sewing>clothing; sewing>computer; sewing>craft; sewing>fashion; sewing>fur; sewing>hobby; sewing>leather; sewing>pin; sewing>sailing; sewing>vein; sex>ant; sex>bird; sex>dna; sex>evolution; sex>female; sex>fish; sex>flower; sex>genetics; sex>human; sex>insect; sex>male; sex>mammal; sex>mushroom; sex>pine; sex>reptile; sex>seed; sex>species; shade>mud; shade>sunglasses; shadow>aircraft; shadow>dimension; shadow>earth; shadow>ghost; shadow>light; shadow>shade; shadow>space; shadow>steam; shadow>sun; shadow>wind; shame>blame; shame>contempt; shame>culture; shame>embarrassment; shame>emotion; shame>humility; shame>punishment; shampoo>acid; shampoo>coconut; shampoo>dirty; shampoo>fragrance; shampoo>hair; shampoo>infant; shampoo>lemon; shampoo>olive; shampoo>peanut; shampoo>rice; shampoo>soap; shampoo>straw; shampoo>surgery; shampoo>water; shampoo>vinegar; shark>circle; shape>curve; shape>dimension; shape>sphere; shape>square; shark>animal; shark>arm; shark>blood; shark>cancer; shark>crystal; shark>earth; shark>eye; shark>god; shark>hair; shark>heart; shark>jaw; shark>kidney; shark>leather; shark>mammal; shark>muscle; shark>nose; shark>ocean; shark>offspring; shark>oxygen; shark>protein; shark>pupil; shark>skate; shark>skeleton; shark>status symbol; shark>supermarket; shark>tail; shed>aluminium; shed>barn; shed>farm; shed>gardening; shed>hobby; shed>jazz; shed>plastic; shed>tool; shed>tunnel; shed>wood; shed>workshop; sheep>abortion; sheep>adaptation; sheep>agriculture; sheep>animal; sheep>antibiotic; sheep>beef; sheep>carpet; sheep>copper; sheep>dialect; sheep>genetics; sheep>goat; sheep>grass; sheep>idiom; sheep>lip; sheep>mammal; sheep>metaphor; sheep>pig; sheep>reproduction; sheep>saint; sheep>tongue; sheep>vaccination; sheep>weed; sheep>virus; sheep>wool; sheep>worm; sheep>paper; sheep>video game; shelter>homelessness; shield>arrow; shield>circle; shield>electronics; shield>leather; shield>metal; shield>police; shield>sword; shield>wood; ship>anchor; ship>boat; ship>cancer; ship>cargo; ship>circle; ship>crab; ship>density; ship>engineer; ship>ferry; ship>fishing; ship>formula; ship>fruit; ship>genetics; ship>globalization; ship>gold; ship>grass; ship>historian; ship>immune system; ship>jail; ship>lake; ship>meat; ship>navy; ship>ocean; ship>port; ship>railway; ship>recycling; ship>river; ship>sail; ship>sailing; ship>sailor; ship>salmon; ship>scrap; ship>sea; ship>strap; ship>weather; ship>wheat; ship>wind; shirt>button; shirt>cotton; shirt>dress; shirt>infant; shirt>jacket; shirt>pocket; shirt>silk; shirt>sleep; shirt>sleeve; shirt>socialist; shirt>sweater; shirt>sweatshirt; shirt>trousers; shirt>waist; shirt>waist; shirt>vest; shirt>wool; shoe>ankle; shoe>archaeologist; shoe>baseball; shoe>basketball; shoe>blister; shoe>bone; shoe>boot; shoe>civilization; shoe>climate; shoe>construction; shoe>copper; shoe>cotton; shoe>culture; shoe>dance; shoe>dancing; shoe>design; shoe>dog; shoe>elephant; shoe>fashion; shoe>foot; shoe>friction; shoe>glove; shoe>golf; shoe>heel; shoe>hip; shoe>horse; shoe>human; shoe>hunting; shoe>ice cream; shoe>knee; shoe>leather; shoe>marathon; shoe>metal; shoe>mining; shoe>mosque; shoe>museum; shoe>peasant; shoe>plastic; shoe>police; shoe>revenue; shoe>rice; shoe>rubber; shoe>running; shoe>sandal; shoe>skateboarding; shoe>ski; shoe>skating; shoe>slavery; shoe>snow; shoe>status symbol; shoe>steel; shoe>turkey; shoe>uniform; shoe>water; shoe>wood; shooting>combat; shooting>crime; shooting>hunting; shooting>missile; shooting>rocket; shooting>weapon; shop>market; shop>retail; shop>shopping; shop>workshop; shopkeeper>management; shopping>ad; shopping>brand; shopping>business; shopping>department store; shopping>disposable income; shopping>leisure; shopping>logo; shopping>marketing; shopping>negotiation; shopping>pharmacy; shopping>price; shopping>relegation; shopping>retail; shopping>supermarket; shopping>trade; shore>beach; shore>coast; shore>erosion; shore>geology; shore>lake; shore>ocean; shore>sea; shore>soil; shorts>basketball; shorts>dress; shorts>garment; shorts>jeans; shorts>pocket; shorts>skirt; shorts>sport; shorts>trousers; short>shooting; shoulder>bat; shoulder>joint; shoulder>pain; show>concert; show>theatre; shower>bathroom; shower>curtain; shower>door; shower>efficiency; shower>hygiene; shower>shampoo; shower>soap; shower>swimming pool; shower>waterfall; shuttle>public transport; shyness>aggression; shyness>anxiety; shyness>child; shyness>conversation; shyness>discomfort; shyness>family; shyness>fear; shyness>feeling; shyness>gene; shyness>hypothesis; shyness>panic; shyness>pregnancy; shyness>proximity; shyness>psychology; shyness>self-confidence; sibling>aggression; sibling>cousin; sibling>dna; sibling>father; sibling>hostility; sibling>inheritance; sibling>love; sibling>mother; sickness>disease; sickness>illness; side effect>drug; side effect>medicine; side effect>pain; side effect>x-ray; side>pirate; side>slavery; side>turkey; sightseeing>tourism; sign>biology; sign>coincidence; sign>communication; sign>flag; sign>full stop; sign>gesture; sign>icon; sign>indication; sign>language; sign>logo; sign>medicine; sign>notice; sign>people; sign>philosophy; sign>poetry; sign>religion; sign>science; sign>signature; sign>symbol; sign>symptom; sign>thunder; signal>telecommunications; signal>traffic light; silence>anger; silence>communication; silence>composer; silence>debate; silence>emotion; silence>mobile phone; silence>piano; silence>sound; silence>speech; silk>angle; silk>ant; silk>bee; silk>carpet; silk>dress; silk>electricity; silk>fibre; silk>fly; silk>glue; silk>light; silk>monopoly; silk>parachute; silk>protein; silk>shirt; silk>spider; silk>tobacco; silk>trade; silk>triangle; silk>turkey; silk>wasp; silver>aluminium; silver>bacteria; silver>brass; silver>carbon; silver>coin; silver>concentration; silver>copper; silver>culture; silver>diamond; silver>exposive; silver>fiction; silver>gold; silver>hammer; silver>infection; silver>iron; silver>lead; silver>metal; silver>mirror; silver>myth; silver>ozone; silver>planet; silver>salt; silver>silk; silver>steel; silver>tea; silver>tin; silver>wine; simplicity>beauty; simplicity>complexity; simplicity>elegance; simplicity>truth; simplification>validity; simulation>aircraft; simulation>biology; simulation>chemistry; simulation>economics; simulation>education; simulation>engineering; simulation>experiment; simulation>film; simulation>finance; simulation>function; simulation>lie; simulation>physics; simulation>prediction; simulation>risk; simulation>scenario; simulation>software; simulation>statistics; simulation>technology; simulation>television; simulation>terrorism; simulation>training; simulation>truth; simulation>video game; simulation>virtual reality; sin>blame; sin>evil; sin>heaven; sin>hell; sin>vanity; sincerity>honesty; sincerity>irony; sincerity>virtue; singing>singing; singing>audition; singing>bird; singing>chest; singing>choir; singing>composer; singing>consonant; singing>culture; singing>dolphin; singing>ear; singing>harmy; singing>hip-hop; singing>human; singing>immune system; singing>jazz; singing>lip; singing>lyrics; singing>melody; singing>microphone; singing>music; singing>neck; singing>opera; singing>rhyme; singing>rhythm; singing>security; singing>song; singing>speech; singing>tongue; singing>whale; singing>vowel; single>slang; sink>bathroom; sink>concrete; sink>flower; sink>frying pan; sink>glass; sink>kitchen; sink>noise; sink>plastic; sink>soap; sink>steel; sink>wood; sir>ambassador; sir>inspector; sir>lady; sir>madam; sir>police; sir>professor; sir>slang; siren>song; sister>sibling; sister-in-law>wife; site>construction; site>website; sitting room>living room; size>area; size>dimension; size>height; size>length; size>measurement; size>statistics; size>width; size>volume; skate>animal; skateboarding>skateboarding; skateboard>turn; skateboarding>aluminium; skateboarding>bruiise; skateboarding>profession; skateboarding>skateboard; skateboarding>surfing; skateboarding>transportation; skating>ice skating; skating>skateboarding; skeleton>adaptation; skeleton>animal; skeleton>ant; skeleton>beak; skeleton>bone; skeleton>coral; skeleton>ear; skeleton>elephant; skeleton>fish; skeleton>flight; skeleton>horse; skeleton>human; skeleton>infant; skeleton>insect; skeleton>jaw; skeleton>muscle; skeleton>nerve; skeleton>nose; skeleton>shark; skeleton>structure; skeleton>tongue; ski>skiing; ski>snowboarding; skiing>ski; skiing>snow; skiing>snowboarding; skill>baker; skill>economy; skill>empathy; skill>energy; skill>language; skill>leadership; skill>learning; skill>motivation; skill>respect; skill>self; skill>teamwork; skill>technology; skill>time; skin>animal; skin>bacteria; skin>bird; skin>blood; skin>body; skin>bone; skin>carbon dioxide; skin>cattle; skin>clothing; skin>cow; skin>fat; skin>feather; skin>fish; skin>frog; skin>fur; skin>goat; skin>hair; skin>heat; skin>horse; skin>injury; skin>leather; skin>mammal; skin>muscle; skin>nerves; skin>oxygen; skin>pig; skin>poison; skin>pressure; skin>protein; skin>repair; skin>reptile; skin>scar; skin>sheep; skin>skull; skin>sweat; skin>temperature; skin>touch; skin>water; skirt>culture; skirt>denim; skirt>fashion; skirt>garment; skirt>jeans; skirt>leather; skirt>leg; skirt>man; skirt>trousers; skirt>underwear; skirt>waist; skirt>woman; skirt>ancestor; skull>animal; skull>bird; skull>bone; skull>brain; skull>elephant; skull>face; skull>head; skull>jaw; skull>lion; skull>mammal; skull>mouse; skull>shark; skull>skeleton; sky>agriculture; sky>air; sky>aircraft; sky>astronomy; sky>atmosphere; sky>bat; sky>bird; sky>blue; sky>calendar; sky>city; sky>cloud; sky>dawn; sky>daylight; sky>earth; sky>flight; sky>fog; sky>green; sky>horizon; sky>human; sky>insect; sky>legend; sky>lightning; sky>moonlight; sky>night; sky>ocean; sky>planet; sky>plant; sky>rain; sky>rainbow; sky>seed; sky>shadow; sky>smog; sky>species; sky>star; sky>storm; sky>sun; sky>sunlight; sky>sunset; sky>sunset; sky>thunder; sky>thunderstorm; sky>weather; sky>wind; slang>crime; slang>crowd; slang>dialect; slang>jargon; slang>language; slang>musician; slang>sex; slang>violence; slang>word; slap>fight; slap>mobile phone; slap>slang; slap>wrist; slaughter>massacre; slaughter>murder; slave>slavery; slavery>adoption; slavery>culture; slavery>human rights; slavery>property; slavery>tax; sleep>adolescent; sleep>alarm clock; sleep>bed; sleep>consciousness; sleep>dolphin; sleep>immune system; sleep>insomnia; sleep>memory; sleep>narrative; sleep>reasoning; sleep>tobacco; sleeve>arm; sleeve>garment; sleeve>ribbon; sleeve>shoulder; sleeve>wedding; slogan>phrase; slope>curve; slope>geography; slope>road; slot>castle; smile>amusement; smile>animal; smile>anxiety; smile>ball; smile>dishonesty; smile>embarrassment; smile>emotion; smile>fear; smile>frown; smile>happiness; smile>human; smile>laughter; smile>muscle; smile>pleasure; smile>psychology; smog>carbon monoxide; smog>coal; smog>flu; smog>fog; smog>ozone; smog>smoke; smog>aluminium; smoke>cable; smoke>cancer; smoke>candle; smoke>carbon; smoke>carbon dioxide; smoke>carbon monoxide; smoke>cloud; smoke>copper; smoke>death; smoke>dust; smoke>fire; smoke>firefighter; smoke>fireplace; smoke>fuel; smoke>gas; smoke>iron; smoke>lead; smoke>liquid; smoke>lung; smoke>mist; smoke>oil; smoke>plastic; smoke>poison; smoke>smog; smoke>smoking; smoke>toast; smoke>tobacco; smoke>wood; smoker>smoke; smoker>smoking; smoking>carbon monoxide; smoking>cigarette; smoking>jazz; smoking>lighter; smoking>match; smoking>tobacco; snack>attention; snack>cheese; snack>food; snack>fruit; snack>meal; snack>meat; snack>obesity; snack>seed; snack>sugar; snack>vegetable; snack>vitamin; snake>brass; snake>chicken; snake>digestion; snake>dinosaur; snake>evil; snake>feather; snake>jaw; snake>lung; snake>medicine; snake>mouth; snake>protein; snake>reptile; snake>skeleton; snake>skull; snake>species; snake>worm; snob>advertising; snob>beauty; snob>education; snob>intellect; snob>nationality; snob>pride; snob>wealth; snow>agriculture; snow>carrot; snow>cloud; snow>concrete; snow>crystal; snow>fall; snow>frost; snow>hall; snow>ice; snow>landscape; snow>light; snow>mountain; snow>photography; snow>pressure; snow>river; snow>salt; snow>ski; snow>skiing; snow>snowboarding; snow>space; snow>spectrum; snow>summer; snow>sunlight; snow>water; snow>wind; snowboard>carbon; snowboard>skateboarding; snowboard>ski; snowboard>snowboarding; snowboarding>skateboarding; snowboarding>skiing; snowboarding>skiing; snowboarding>skiing; soap opera>abortion; soap opera>adoption; soap opera>episode; soap opera>fantasy; soap opera>magazine; soap opera>murder; soap opera>rape; soap opera>soap; soap opera>theft; soap opera>trilogy; soap opera>twin; soap>advertising; soap>aluminium; soap>dust; soap>hotel; soap>hygiene; soap>sacrifice; soap>sand; soap>silver; soap>toothpaste; soap>water; soap>wire; soap>wool; socialism>agriculture; socialism>authority; socialism>capitalism; socialism>hierarchy; socialism>human rights; socialism>interest; socialism>materialist; socialism>money; socialism>poverty; socialism>rebellion; socialism>republic; socialism>socialist; socialist>socialism; society>agriculture; society>artificial intelligence; society>business; society>capitalism; society>civilization; society>commerce; society>community; society>cooperation; society>culture; society>education; society>geography; society>government; society>hierarchy; society>history; society>industry; society>infrastructure; society>institution; society>investor; society>language; society>leadership; society>organization; society>religion; society>technology; society>trade; society>tribe; society>wealth; sock>boot; sock>cloth; sock>clothing; sock>cotton; sock>foot; sock>glove; sock>linen; sock>shoe; sock>silk; sock>stocking; sock>sweat; sock>wool; soft drink>acid; soft drink>bottle; soft drink>carbon dioxide; soft drink>cola; soft drink>erosion; soft drink>lemonade; soft drink>milk; soft drink>mineral water; soft drink>obesity; soft drink>sugar; soft drink>supermarket; soft drink>tea; soft drink>water; soft drink>concept; software>data; software>hard drive; software>information; software>logic; software>programmer; software>spreadsheet; software>television; software>video game; soil>aluminium; soil>atmosphere; soil>bacteria; soil>desert; soil>drift; soil>drought; soil>earth; soil>erosion; soil>fat; soil>geology; soil>iron; soil>lead; soil>oxygen; soil>salt; soil>sand; soil>solution; soil>virus; soldier>army; soldier>endurance; soldier>police officer; soldier>profession; solicitor>advocate; solicitor>court; solicitor>lawyer; solicitor>salesman; solidarity>tribe; solitude>anxiety; solitude>creativity; solitude>illusion; solitude>loneliness; solitude>pirate; solitude>privacy; solitude>solitude; solitude>bronze; solution>carbon dioxide; solution>chemistry; solution>concentration; solution>gas; solution>gold; solution>light; solution>liquid; solution>mixture; solution>oil; solution>oxygen; solution>pressure; solution>salt; solution>steel; solution>sugar; solution>temperature; solution>water; son>boy; son>daughter; son>family; son>inheritance; son>law; son>male; son>man; son>parent; son>reproduction; song>author; song>choir; song>composer; song>concert; song>music; song>opera; song>orchestra; song>piano; song>poetry; song>radio; song>rhythm; song>singer; song>singing; soul>angel; soul>consciousness; soul>disability; soul>dream; soul>emotion; soul>essence; soul>heart; soul>heaven; soul>hell; soul>intelligence; soul>life;

suspense>terror; suspense>waiter; sustainability>agriculture; sustainability>atmosphere; sustainability>capitalism; sustainability>carbon; sustainability>civilization; sustainability>climate; sustainability>climate change; sustainability>coal; sustainability>commodity; sustainability>crime; sustainability>earth; sustainability>ecology; sustainability>economics; sustainability>economy; sustainability>energy; sustainability>environmentalist; sustainability>extinction; sustainability>fair; sustainability>fat; sustainability>food; sustainability>forest; sustainability>fruit; sustainability>global warming; sustainability>industry; sustainability>lake; sustainability>law; sustainability>longevity; sustainability>market; sustainability>material; sustainability>meat; sustainability>obesity; sustainability>ocean; sustainability>oxygen; sustainability>population; sustainability>price; sustainability>recycling; sustainability>river; sustainability>science; sustainability>society; sustainability>sun; sustainability>technology; sustainability>transport; sustainability>war; sustainability>water; sustainability>weather; sustainability>vegetable; sustainability>woodland; swan>animal; swan>bird; swan>duck; swan>extinction; swan>species; sweater>button; sweater>cotton; sweater>ice hockey; sweater>jacket; sweater>shirt; sweater>sleeve; sweater>trousers; sweater>t-shirt; sweater>wool; sweater>youth; sweatshirt>sweater; swimming pool>bacteria; swimming pool>basement; swimming pool>basketball; swimming pool>beach; swimming pool>circle; swimming pool>concrete; swimming pool>department store; swimming pool>disability; swimming pool>disease; swimming pool>diving; swimming pool>fountain; swimming pool>hotel; swimming pool>infant; swimming pool>insect; swimming pool>iron; swimming pool>metal; swimming pool>oxygen; swimming pool>ozone; swimming pool>park; swimming pool>plastic; swimming pool>pump; swimming pool>recreation; swimming pool>rectangle; swimming pool>skateboarding; swimming pool>supermarket; swimming pool>toddler; swimming pool>toy; swimming pool>tv; swimming pool>virus; swimming pool>yard; switch>brass; switch>copper; switch>design; switch>electrician; switch>electronics; switch>glass; switch>metal; switch>plastic; switch>steel; sword>blade; sword>bronze; sword>combat; sword>copper; sword>god; sword>history; sword>iron; sword>literature; sword>marial art; sword>parade; sword>shield; sword>steel; sword>turkey; sword>umbrella; sword>uniform; syllable>consonant; syllable>language; syllable>poetry; syllable>rhyme; syllable>word; syllable>vowel; syllabus>communication; syllabus>curriculum; syllabus>education; syllabus>exam; syllabus>grammar; syllabus>professor; syllabus>training; symbol>entity; symbol>history; symbol>icon; symbol>idea; symbol>learning; symbol>logo; symbol>punctuation; symbol>uniform; sympathy>empathy; symptom>blindness; symptom>diagnosis; symptom>disease; symptom>patient; symptom>rash; synonym>adjective; synonym>adverb; synonym>noun; synonym>preposition; system>concrete; system>culture; system>economics; system>engineering; system>institution; system>market; system>person; system>physics; system>property; system>reasoning; system>society; system>structure; table tennis>friction; table tennis>gram; table tennis>sport; tablet>notebook; tail>animal; tail>bird; tail>body; tail>cat; tail>deer; tail>dog; tail>emotion; tail>feather; tail>fish; tail>fly; tail>kangaroo; tail>lion; tail>mammal; tail>monkey; tail>nerves; tail>predator; tail>reptile; takeover>bank; takeover>consideration; takeover>loan; takeover>majority; takeover>management; takeover>merger; tale>narrative; talent>celebrity; talk>conversation; talk>interaction; talk>speech; talks>battle; tank>bomb; tank>bridge; tank>deception; tank>electronics; tank>laser; tank>petrol; tank>plastic; tank>railway; tank>system; tank>telescope; taste>acid; taste>alcohol; taste>appetite; taste>banana; taste>beer; taste>blood; taste>brain; taste>cheese; taste>coffee; taste>evolution; taste>foat; taste>food; taste>fruit; taste>genetics; taste>grape; taste>lemon; taste>meat; taste>medicine; taste>melon; taste>milk; taste>salt; taste>sense; taste>soft drink; taste>sugar; taste>tea; taste>tongue; taste>wine; tax>alcohol; tax>bridge; tax>business; tax>canal; tax>capitalism; tax>currency; tax>democracy; tax>economics; tax>euro; tax>fee; tax>health care; tax>inflation; tax>law; tax>liberty; tax>market; tax>peasant; tax>pension; tax>petrol; tax>politics; tax>price; tax>property; tax>public transport; tax>recession; tax>road; tax>society; tax>tobacco; tax>trade; tax>wealth; tax>welfare; taxpayer>tax; tea>alcohol; tea>aluminium; tea>butter; tea>cancer; tea>coffee; tea>culture; tea>fruit; tea>honey; tea>jam; tea>lemon; tea>meu; tea>obesity; tea>slang; tea>sugar; tea>tree; tea>turkey; tea>water; tea>whisky; tea>virus; tea>vitamin; teacher>allegation; teacher>classroom; teacher>college; teacher>curriculum; teacher>discipline; teacher>education; teacher>engineer; teacher>euro; teacher>goal; teacher>individual; teacher>knowledge; teacher>lawyer; teacher>lecturer; teacher>priest; teacher>primary school; teacher>profession; teacher>professional; teacher>professor; teacher>religion; teacher>retirement; teacher>school; teacher>secondary school; teacher>skill; teacher>student; teacher>tutor; teacher>university; teacher>vow; teaching>education; team>animal; team>business; team>chess; team>community; team>complexity; team>concept; team>crew; team>dog; team>football; team>game; team>horse; team>management; team>partnership; team>peer pressure; team>project; team>sport; team>success; team>system; team>teamwork; teamwork>clothing; teamwork>collaboration; teamwork>health care; teamwork>team; teaspoon>coffee; teaspoon>cooking; teaspoon>cutlery; teaspoon>ice cream; teaspoon>recipe; teaspoon>spoon; teaspoon>tea; technician>artist; technician>manufacturing; technician>mechanic; technician>presenter; technician>professional; technician>technology; technician>theory; technician>tool; technician>training; technique>skill; technique>technology; techno>capitalism; techno>disc jockey; techno>disco; techno>economy; techno>harmony; techno>hip-hop; techno>paradigm; techno>performance; techno>rhythm; techno>time; technology>agriculture; technology>architecture; technology>brass; technology>bronze; technology>chemistry; technology>clock; technology>communication; technology>computer; technology>construction; technology>copper; technology>craft; technology>dolphin; technology>earth; technology>economy; technology>electricity; technology>energy; technology>engineering; technology>flight; technology>gold; technology>hierarchy; technology>history; technology>industry; technology>infrastructure; technology>language; technology>lead; technology>leisure; technology>machine; technology>manufacturing; technology>medicine; technology>mining; technology>paradigm; technology>physics; technology>politician; technology>pollution; technology>radio; technology>safety; technology>satellite; technology>science; technology>scientist; technology>silk; technology>silver; technology>society; technology>spoon; technology>steel; technology>system; technology>telephone; technology>television; technology>tool; technology>train; technology>transport; technology>transportation; technology>weapon; technology>wheel; technology>wood; telephone>business; telephone>consumer; telephone>invention; telephone>microphone; telephone>mobile phone; telephone>radio; telephone>sound; telescope>astronomy; telescope>earth; telescope>glass; telescope>ice; telescope>mirror; telescope>radio; telescope>satellite; telescope>trace; telescope>water; telescope>x-ray; television>advertising; television>angle; television>audience; television>copper; television>electronics; television>lead; television>news; television>radio; television>science fiction; television>soap opera; telly>television; temper>archaeology; temper>atmosphere; temper>season; temper>temperature; temper>time; temperature>atom; temperature>biology; temperature>chemistry; temperature>density; temperature>energy; temperature>gas; temperature>geology; temperature>heat; temperature>kilogram; temperature>liquid; temperature>physics; temperature>protein; temperature>ratio; temperature>speed; temperature>sun; temperature>thermometer; temperature>x-ray; temple>cathedral; temple>chapel; temple>god; temple>mosque; temple>prayer; temple>sacifice; temple>turkey; temple>warehouse; temptation>advertising; temptation>curiosity; temptation>marketing; temptation>persuasion; temptation>religion; temptation>sin; tenderness>affection; tenderness>love; tennis>baseball; tennis>referee; tension>suspense; tent>airport; tent>aluminium; tent>boat; tent>camping; tent>campsite; tent>circus; tent>cotton; tent>earthquake; tent>fire; tent>foat; tent>metal; tent>pole; tent>sheep; tent>structure; tent>theatre; tent>war; tent>wood; terminal>port; terminal>suffix; terms>term; terrace>river; terrace>stream; terror>terrorism; terrorism>assault; terrorism>consensus; terrorism>crime; terrorism>faith; terrorism>fear; terrorism>war; terrorism>hostage; terrorism>human rights; terrorism>law; terrorism>peace; terrorism>poison; terrorism>politics; terrorism>publicity; terrorism>rebellion; terrorism>riot; terrorism>robbery; terrorism>security; terrorism>telecommunications; terrorism>turkey; terrorism>uniform; terrorism>war; terrorism>violence; terrorist>terrorism; test>experiment; text>literature; text>textbook; text>book>evolution; theatre>actor; theatre>audience; theatre>ballet; theatre>collaboration; theatre>composer; theatre>culture; theatre>dance; theatre>dialogue; theatre>drama; theatre>fiction; theatre>humour; theatre>institution; theatre>literature; theatre>music; theatre>opera; theatre>performance; theatre>poetry; theatre>song; theatre>tragedy; theatre>wine; theft>bicycle; theft>blackmail; theft>burglary; theft>consent; theft>crime; theft>dishonesty; theft>fraud; theft>jail; theft>money; theft>property; theft>robbery; theft>synonym; theme>principle; theme>synonym; theme>analysis; theory>architecture; theory>art; theory>astronomy; theory>biology; theory>chemistry; theory>climate change; theory>diseases; theory>economics; theory>education; theory>engineering; theory>evidence; theory>evolution; theory>experiment; theory>explanation; theory>fact; theory>film; theory>geology; theory>global warming; theory>hypothesis; theory>idea; theory>literature; theory>logic; theory>music; theory>nature; theory>observation; theory>philosophy; theory>physics; theory>politics; theory>prediction; theory>probability; theory>psychology; theory>reason; theory>science; theory>statistics; theory>technology; theory>truth; theory>understanding; therapy>coaching; therapy>cold; therapy>cure; therapy>drug; therapy>education; therapy>electricity; therapy>energy; therapy>exercise; therapy>food; therapy>gene; therapy>gold; therapy>heat; therapy>junk food; therapy>light; therapy>matter; therapy>medication; therapy>medicine; therapy>ozone; therapy>radiation; therapy>reading; therapy>risk; therapy>salt; therapy>side effect; therapy>sleep; therapy>smell; therapy>sound; therapy>temperature; therapy>vaccine; therapy>water; therapy>virus; thermometer>aircraft; thermometer>atmosphere; thermometer>fever; thermometer>health care; thermometer>heater; thermometer>temperature; thesis>bed; thesis>essay; thesis>intellectual; thesis>professor; thesis>proposition; thesis>research; thesis>university; thief>theft; thigh>blood; thigh>bone; thigh>hip; thigh>knee; thigh>muscle; thigh>nerve; thinker>intellectual; thirst>brain; thirst>instinct; thirst>kidney; thirst>salt; thought>artificial intelligence; thought>attention; thought>consciousness; thought>goal; thought>human; thought>idea; thought>imagination; thought>individual; thought>mind; thought>philosophy; thought>psychology; thought>reasoning; thought>religion; thought>science; thought>sense; thought>society; thought>symptom; threshold>perception; threshold>sense; throat>neck; throne>angel; throne>cathedral; throne>emperor; throne>god; throne>music; throne>palace; throne>pie; throne>privilege; throne>religion; throne>slang; throne>temple; throne>toilet; thumb>ankle; thumb>bird; thumb>finger; thumb>foot; thumb>hand; thumb>tool; thumb>walk; thunder>aircraft; thunder>explosion; thunder>inquiry; thunder>light; thunder>lightning; thunder>pressure; thunder>sound; thunder>temperature; thunder>thunderstorm; thunder>thursday; thunder>storm; thunder>storm>carbon dioxide; thunder>storm>cloud; thunder>storm>dust; thunder>storm>energy; thunder>storm>fall; thunder>storm>god; thunder>storm>hail; thunder>storm>lightning; thunder>storm>rain; thunder>storm>rainforest; thunder>storm>soil; thunder>storm>storm; thunder>storm>summer; thunder>storm>thunder; thunder>storm>tornado; thunder>storm>weather; thunder>storm>wind; thursday>calendar; thursday>earth; thursday>friday; thursday>green; thursday>heaven; thursday>saint; thursday>wednesday; tick>animal; tick>blood; tick>mosquito; tick>toddler; tick>virus; tide>adaptation; tide>average; tide>coast; tide>global warming; tide>sun; tide>weather; tiger>animal; tiger>bird; tiger>camel; tiger>cattle; tiger>climate change; tiger>crocodile; tiger>dna; tiger>dog; tiger>dolphin; tiger>elephant; tiger>extinction; tiger>female; tiger>fish; tiger>flag; tiger>fox; tiger>gene; tiger>habitat; tiger>honey; tiger>horse; tiger>lake; tiger>leopard; tiger>lion; tiger>male; tiger>mammal; tiger>monkey; tiger>novel; tiger>polar bear; tiger>pond; tiger>prey; tiger>pupul; tiger>reproduction; tiger>river; tiger>scientist; tiger>snake; tiger>turkey; tiger>water; tiger>west; tiger>whale; tights>ball; tights>basketball; tights>costume; tights>cotton; tights>dance; tights>garment; tights>infant; tights>leg; tights>pants; tights>shorts; tights>silk; tights>toddler; tights>uniform; tights>waist; tights>wool; time>astronomy; time>awareness; time>calendar; time>century; time>chart; time>clock; time>day; time>decade; time>dimension; time>documentary; time>earth; time>economics; time>education; time>fiction; time>fortnight; time>future; time>generation; time>god; time>history; time>hour; time>industry; time>law; time>light; time>machine; time>measurement; time>millennium; time>minute; time>month; time>music; time>noon; time>number; time>perception; time>phenomenon; time>philosophy; time>plan; time>present; time>quantity; time>religion; time>result; time>sand; time>science; time>season; time>second; time>sequence; time>society; time>space; time>technology; time>television; time>theatre; time>transport; time>watch; time>week; time>year; timetable>calendar; timing>time; tin>acid; tin>air; tin>bronze; tin>carbon; tin>copper; tin>crystal; tin>diamond; tin>earth; tin>glass; tin>gold; tin>iron; tin>kilogram; tin>lead; tin>metal; tin>oxygen; tin>sun; tin>trade; tin>water; tip>x-ray; title>adjective; title>advocate; title>ambassador; title>ant; title>brother; title>chancellor; title>citizen; title>commander; title>count; title>county; title>delegate; title>emperor; title>empire; title>female; title>gentleman; title>judge; title>king; title>lady; title>leadership; title>magistrate; title>male; title>mayor; title>miss; title>mother; title>mr; title>mrs; title>nurse; title>official; title>police officer; title>president; title>priest; title>prince; title>princess; title>professor; title>realm; title>saint; title>secretary; title>sir; title>sister; title>solicitor; title>uncle; toast>bread; toast>breakfast; toast>butter; toast>fireplace; toast>food; toast>fork; toast>heat; toast>jam; toast>oven; tobacco>cancer; tobacco>capitalism; tobacco>cigarette; tobacco>cigar; tobacco>disaster; tobacco>drug; tobacco>evolution; tobacco>gardening; tobacco>genetics; tobacco>hail; tobacco>harvest; tobacco>heart; tobacco>heaven; tobacco>herb; tobacco>honey; tobacco>insect; tobacco>lover; tobacco>seed; tobacco>stroke; tobacco>tea; tobacco>turkey; tobacco>wasp; today>present; toddler>adjective; toddler>ball; toddler>book; toddler>chair; toddler>childhood; toddler>doll; toddler>furniture; toddler>game; toddler>infant; toddler>noun; toddler>song; toddler>spoon; toddler>telephone; toddler>vocabulary; toddler>word; toe>animal; toe>cat; toe>finger; toe>foot; toe>hand; toe>human; toe>joint; toe>walking; toilet>ballet; toilet>castle; toilet>dialect; toilet>emergency; toilet>pottery; toilet>sink; toilet>train; toilet>video game; toilet>wilderness; tomato>apple; tomato>banana; tomato>berry; tomato>commerce; tomato>cucumber; tomato>dessert; tomato>drink; tomato>festival; tomato>flower; tomato>fruit; tomato>garlic; tomato>genetics; tomato>leaf; tomato>main course; tomato>melon; tomato>pasta; tomato>pizza; tomato>potato; tomato>salt; tomato>soup; tomato>tobacco; tomato>vegetable; tomb>burial; tomb>cemetary; tomb>saint; tomb>cricket; tomb>energy; tomb>slang; tomb>steel; tomb>volume; tone>note; tongue>butterfly; tongue>cat; tongue>cod; tongue>dog; tongue>duck; tongue>food; tongue>frog; tongue>human; tongue>language; tongue>memory; tongue>mouth; tongue>nerve; tongue>phenomenon; tongue>recollection; tongue>taste; tool>agriculture; tool>animal; tool>archaeology; tool>bird; tool>clock; tool>computer; tool>elephant; tool>glasses; tool>glove; tool>goal; tool>hammer; tool>human; tool>knife; tool>lighter; tool>matter; tool>monkey; tool>phone; tool>rocket; tool>ruler; tool>spreadsheet; tool>technology; tool>truck; tool>university; tool>dolphin; tool>elephant; tool>fish; tool>foad; tool>horse; tool>jaw; tool>mammal; tool>mouth; tool>rabbit; tool>reptile; tool>shark; tool>snake; tool>whale; toothache>pain; toothache>temperature; toothache>tooth; toothache>x-ray; toothbrush>bacteria; toothbrush>bone; toothbrush>dentist; toothbrush>feather; toothbrush>salt; toothbrush>tooth; toothbrush>toothpaste; toothbrush>water; toothpaste>food; toothpaste>lead; toothpaste>lemon; toothpaste>pine;

toothpaste-toothbrush; toothpaste-whisky; top>archaeology; top>dice; top>gambling; top>iron; top>plastic; top>rope; top>toy; top>wood; torch>castle; torch>death; torch>hope; torch>love; torch>wood; tornado>air; tornado>camera; tornado>climate; tornado>cloud; tornado>dust; tornado>global warming; tornado>temperature; tornado>thunderstorm; tornado>wind; torture>civilian; torture>famine; torture>hell; torture>hostage; torture>human rights; torture>injury; torture>justice; torture>medication; torture>murder; torture>murderer; torture>pain; torture>punishment; torture>rape; torture>rebellion; torture>refugee; torture>revenge; torture>slave; torture>suffering; torture>terrorist; torture>war; toughness>energy; tourism>resilience; tour>tourism; tourism>airline; tourism>airport; tourism>business; tourism>carbon footprint; tourism>culture; tourism>employment; tourism>export; tourism>hotel; tourism>itinerary; tourism>leisure; tourism>chassis; tourism>recreation; tourism>resort; tourism>terrorism; tourism>theatre; tourism>transport; tourism>travel; tourism>turkey; tourists>tourism; tournament>board game; tournament>chess; tournament>competition; tournament>debate; tournament>film; tournament>game; tournament>sport; tournament>tennis; towel>barber; towel>beach; towel>blanket; towel>boxing; towel>cloth; towel>dance; towel>garment; towel>hygiene; towel>pawn; towel>radio; towel>skirt; towel>smoke; towel>television; towel>turkey; tower>chimney; tower>height; tower>agriculture; town>cathedral; town>city; town>commerce; town>county; town>factory; town>fair; town>house; town>industry; town>market; town>mining; town>police; town>suburb; town>turkey; town>village; toy>advertising; toy>aircraft; toy>animal; toy>apple; toy>auction; toy>baby; toy>ball; toy>board game; toy>bone; toy>book; toy>car; toy>castle; toy>child; toy>cloth; toy>creativity; toy>dice; toy>doll; toy>dolphin; toy>exercise; toy>farm; toy>film; toy>game; toy>gift; toy>girl; toy>globalization; toy>grass; toy>hand; toy>house; toy>human; toy>industry; toy>infant; toy>injury; toy>innovation; toy>inquiry; toy>monkey; toy>museum; toy>pattern; toy>pet; toy>plastic; toy>problem; toy>puzzle; toy>science fiction; toy>sport; toy>tank; toy>television; toy>tomb; toy>top; toy>whistle; toy>video game; toy>wood; trace>trail; track>song; track>trail; tracksuit>clothing; tracksuit>jacket; tracksuit>shirt; tracksuit>shorts; tracksuit>sport; tracksuit>sweater; tracksuit>trousers; tractor>agriculture; tractor>brake; tractor>clutch; tractor>construction; tractor>crop; tractor>engine; tractor>farm; tractor>farmer; tractor>farming; tractor>garden; tractor>grass; tractor>hazard; tractor>machine; tractor>railway; tractor>repair; tractor>truck; tractor>vehicle; trade>bronze; trade>business; trade>buyer; trade>civilization; trade>commerce; trade>commodity; trade>currency; trade>demand; trade>department store; trade>earnings; trade>economics; trade>export; trade>globalization; trade>gold; trade>industrialization; trade>mail; trade>market; trade>money; trade>monopoly; trade>ownership; trade>price; trade>retail; trade>retailer; trade>silver; trade>spice; trade>subsidy; trade>tin; tradition>adjective; tradition>archaeology; tradition>belief; tradition>biology; tradition>creativity; tradition>generation; tradition>globalization; tradition>hierarchy; tradition>inheritance; tradition>myth; tradition>picnic; tradition>psychology; tradition>rhythm; traffic light>lorry; traffic light>public transport; traffic light>roundabout; traffic>animal; traffic>bicycle; traffic>bus; traffic>lane; traffic>law; traffic>parking; traffic>pedestrian; traffic>roundabout; traffic>rush hour; traffic>traffic jam; traffic>traffic light; traffic>vehicle; tragedy>composer; tragedy>culture; tragedy>dance; tragedy>definition; tragedy>destiny; tragedy>dignity; tragedy>drama; tragedy>elite; tragedy>fear; tragedy>goat; tragedy>god; tragedy>law; tragedy>luck; tragedy>male; tragedy>narrative; tragedy>opera; tragedy>paradox; tragedy>person; tragedy>pity; tragedy>poetry; tragedy>reversal; tragedy>ritual; tragedy>society; tragedy>structure; tragedy>suffering; trail>autumn; trail>bridge; trail>climbing; trail>cycling; trail>erosion; trail>horse; trail>lane; trail>road; trail>running; trail>ski; trail>snow; trail>soldier; trail>wheelchair; trail>woodland; train>airport; train>bicycle; train>cargo; train>coal; train>food; train>machine; train>money; train>passenger; train>praise; train>public transport; train>redevelopment; train>ship; train>tram; train>truck; train>vehicle; train>wheel; train>wheelchair; trainee>college; trainee>university; training>artificial intelligence; training>capacity; training>career; training>college; training>combat; training>education; training>employment; training>feedback; training>god; training>knowledge; training>learning; training>profession; training>religion; training>ritual; training>robot; training>skill; training>tool; training>war; tram>bus; tram>cable; tram>cargo; tram>infrastructure; tram>noise; tram>specification; tram>spy; tram>wheelchair; translation>accuracy; translation>actor; translation>adaptation; translation>ambiguity; translation>artist; translation>business; translation>chemistry; translation>communication; translation>concept; translation>culture; translation>devil; translation>dictionary; translation>film; translation>grammar; translation>idiom; translation>language; translation>literature; translation>music; translation>musician; translation>novel; translation>novelist; translation>opera; translation>perfection; translation>physics; translation>poet; translation>poetry; translation>rhythm; translation>science; translation>technology; translation>theatre; translation>vocabulary; translation>word; translation>writing; transport>action; transport>airport; transport>beer; transport>boat; transport>bridge; transport>bus; transport>bus station; transport>cable; transport>canal; transport>carbon dioxide; transport>cargo; transport>cattle; transport>city; transport>coal; transport>concrete; transport>construction; transport>debt; transport>dirt; transport>education; transport>electronics; transport>escalator; transport>fashion; transport>ferry; transport>global warming; transport>globalization; transport>government; transport>helicopter; transport>horse; transport>human; transport>infrastructure; transport>lake; transport>landing; transport>leisure; transport>machine; transport>ocean; transport>passenger; transport>pedestrian; transport>pressure; transport>public transport; transport>railway; transport>recreation; transport>risk; transport>river; transport>road; transport>rocket; transport>roundabout; transport>running; transport>sea; transport>ship; transport>skiing; transport>smog; transport>soil; transport>steam; transport>steel; transport>street; transport>tax; transport>team; transport>technology; transport>tourism; transport>trade; transport>trail; transport>train; transport>tram; transport>truck; transport>walking; transport>warehouse; transport>water; transport>vehicle; transport>wheel; transport>willing; transport>wind; transport>wood; transport>transport>transport; trash>junk food; trash>litter; trash>waste; travel>bicycle; travel>boat; travel>bus; travel>culture; travel>cycling; travel>exploration; travel>holiday; travel>itinerary; travel>passport; travel>pedestrian; travel>people; travel>public transport; travel>recreation; travel>refugee; travel>research; travel>safety; travel>tourism; travel>trade; travel>train; travel>transport; travel>walking; travel>van; travel>vehicle; tray>photography; tray>plastic; tray>rectangle; treasure>motivation; treasure>pirate; treasure>protagonist; treasure>war; treat>threat; treat>treaty; treatment>therapy; treaty>constitution; treaty>signature; treaty>slavery; treaty>torture; tree>apple; tree>banana; tree>barbecue; tree>bark; tree>carbon; tree>carbon dioxide; tree>chocolate; tree>construction; tree>drought; tree>forest; tree>fruit; tree>fuel; tree>god; tree>habitat; tree>paper; tree>pine; tree>plant; tree>rainforest; tree>species; tree>tea; tree>wood; trek>trekking; trekking>transport; trekking>walking; trend>business; trend>culture; trend>fashion; trend>population; trend>technology; trial>appeal; trial>authority; trial>court; trial>crime; trial>government; trial>innocence; trial>judge; trial>jury; trial>law; trial>prosecution; triangle>angle; triangle>architect; triangle>astronomy; triangle>circle; triangle>construction; triangle>dimension; triangle>earthquake; triangle>nature; triangle>rectangle; triangle>shape; triangle>sphere; tribe>archaeology; tribe>civilization; tribe>leadership; tribe>nation; tribe>civilization; tribute>hostage; tribute>philosophy; tribute>province; tribute>subsidy; tribute>war; trilogy>fantasy; trilogy>fiction; trilogy>literature; trilogy>novel; trilogy>science fiction; trilogy>video game; trip>injury; trip>tourism; trip>travel; trophy>animal; trophy>boxing; trophy>hunting; trophy>medal; trophy>silver; trophy>television; trouble>challenge; trouble>risk; trousers>baseball; trousers>call; trousers>clothing; trousers>cotton; trousers>denim; trousers>dress; trousers>fashion; trousers>hip; trousers>history; trousers>jeans; trousers>shirt; trousers>shorts; trousers>skateboarding; trousers>skirt; trousers>underpants; trousers>underwear; trousers>waist; truck>carbon dioxide; truck>engine; truck>global warming; truck>steel; truck>ton; truck>water; truck>wheel; trumpet>army; trumpet>brass; trumpet>harmony; trumpet>orchestra; trumpet>rectangle; trumpet>belief; truth>concept; truth>contradiction; truth>debate; truth>disposition; truth>essence; truth>existence; truth>fact; truth>gender; truth>god; truth>imagination; truth>information; truth>inquiry; truth>intelligence; truth>judgment; truth>knowledge; truth>law; truth>lie; truth>logic; truth>mirror; truth>philosophy; truth>proposition; truth>reality; truth>reason; truth>religious; truth>science; truth>sense; truth>time; truth>understanding; t-shirt>advertising; t-shirt>black; t-shirt>clothing; t-shirt>ink; t-shirt>ironing; t-shirt>laundry; t-shirt>marketing; t-shirt>shirt; t-shirt>souvenir; t-shirt>vest; t-shirt>yellow; tube>surfing; tube>television; tuesday>election; tuesday>monday; tuesday>pink; tuesday>saint; tuesday>wednesday; tuna>dolphin; tuna>extinction; tuna>oil; tuna>predator; tuna>protein; tuna>shark; tuna>species; tuna>whale; tune>melody; tunnel>canal; tunnel>carbon monoxide; tunnel>coal; tunnel>firefighter; tunnel>flood; tunnel>mining; tunnel>roof; tunnel>tool; tunnel>traffic; tunnel>turkey; tunnel>weapon; turkey>democracy; turkey>helicopter; turkey>recession; turkey>republic; turkey>tank; turkey>volcano; turn>turning; turnover>revenue; tutor>classroom; tutor>education; tutor>lecturer; tutor>professional; tutor>secondary school; tutor>seminar; tutor>student; tutor>teaching; tv>television; twin>brain; twin>cat; twin>cattle; twin>deer; twin>dog; twin>genetics; twin>heart; twin>liver; twin>offspring; twin>pregnancy; twin>psychology; twin>sheep; twin>sibling; umbrella>cotton; umbrella>priest; umbrella>procession; umbrella>slang; umbrella>steel; umbrella>storm; umbrella>temple; umbrella>tent; uncertainty>certainty; uncertainty>economics; uncertainty>engineering; uncertainty>error; uncertainty>finance; uncertainty>gambling; uncertainty>game; uncertainty>insurance; uncertainty>philosophy; uncertainty>physics; uncertainty>probability; uncertainty>psychology; uncertainty>risk; uncertainty>statistics; uncertainty>weather forecast; uncle>aunt; uncle>brother; uncle>brother-in-law; uncle>family; uncle>parent; underpants>button; understanding>anxiety; understanding>awareness; understanding>brain; understanding>concept; understanding>electronics; understanding>engineering; understanding>explanation; understanding>knowledge; understanding>language; understanding>message; understanding>perception; understanding>person; understanding>prediction; understanding>psychiatrist; understanding>science fiction; understanding>thought; undertaking>company; unemployment>debt; unemployment>disability; unemployment>globalization; unemployment>homelessness; unemployment>inflation; unemployment>percentage; unemployment>productivity; unemployment>recession; unemployment>self-esteem; unemployment>training; unemployment>xenophobia; uniform>air force; uniform>airline; uniform>bank; uniform>brand; uniform>clothing; uniform>employer; uniform>health care; uniform>hotel; uniform>organization; uniform>police; uniform>post office; uniform>prison; uniform>restaurant; uniform>retailer; uniform>school; uniform>shirt; uniform>skirt; uniform>trousers; uniform>truck; uniform>alliance; unit>apartment; unit>statistics; university>astronomy; university>engineering; university>grammar; university>laboratory; university>logic; university>music; university>religion; university>research; university>science; university>seminar; unrest>rebellion; unrest>riot; upgrade>software; usage>grammar; usage>language; user>consumer; vaccination>bacteria; vaccination>cancer; vaccination>cow; vaccination>immune system; vaccination>infection; vaccination>protein; vaccination>vaccine; vaccination>virus; vaccine>antibiotic; vaccine>dna; vaccine>human; vaccine>immune system; vaccine>infection; vaccine>liberty; vaccine>medication; vaccine>protein; wage>employee; wage>employer; wage>employment; wage>salary; waist>beauty; waist>fashion; waist>fat; waist>hip; waist>jewellery; waist>obesity; waist>rib; validity>argument; validity>contradiction; validity>logic; walk>walking; walker>pedestrian; walking>anxiety; walking>bone; walking>cancer; walking>concentration; walking>cycling; walking>endurance; walking>exercise; walking>hand; walking>health; walking>hobby; walking>human; walking>knee; walking>learning; walking>memory; walking>nature; walking>obesity; walking>pedestrian; walking>public transport; walking>robot; walking>running; walking>sheep; walking>stroke; walking>trail; walking>transport; wall>air; wall>architecture; wall>ceiling; wall>city; wall>fence; wall>fencing; wallet>cash; wallet>copper; wallet>credit card; wallet>denim; wallet>exercise; wallet>fabric; wallet>handbag; wallet>hotel; wallet>id card; wallet>itinerary; wallet>leather; wallet>paper; wallet>passport; wallet>photograph; wallet>pocket; wallet>shoe; wallet>travel; wallet>agriculture; valley>castle; valley>cliff; valley>climate; valley>earth; valley>erosion; valley>flood; valley>geography; valley>geology; valley>river; valley>stream; valley>sunlight; valley>temperature; valley>waterfall; valley>village; van>airport; van>ambulance; van>car; van>hotel; van>parking; van>truck; van>vehicle; vandalism>abuse; vandalism>beauty; vandalism>crime; vandalism>criminal; vandalism>culture; vandalism>gang; vandalism>history; vandalism>imprisonment; vandalism>life; vandalism>mayor; vandalism>monument; vandalism>punishment; vandalism>riot; vanity>death; vanity>god; vanity>image; vanity>justice; vanity>pride; vanity>selfishness; vanity>woman; war>ant; war>common sense; war>deception; war>democracy; war>failure; war>famine; war>inheritance; war>market; war>peace; war>revenge; war>society; war>treathy; war>violence; ward>hospital; wardrobe>castle; wardrobe>chest of drawers; wardrobe>clothes; wardrobe>cupboard; wardrobe>oak; wardrobe>palace; wardrobe>tray; wardrobe>airport; warehouse>computer; warehouse>customs; warehouse>database; warehouse>manufacturer; warehouse>preservation; warehouse>railway; warehouse>transport; warmth>heat; warrior>combat; warrior>courage; warrior>faith; warrior>honour; warrior>loyalty; warrior>mercy; warrior>rebellion; warrior>soldier; warrior>tribe; warrior>war; warrior>virtue; vase>flower; washing machine>bacteria; washing machine>carbon dioxide; washing machine>clothing; washing machine>clutch; washing machine>housewife; washing machine>inventor; washing machine>ironing; washing machine>laundry; washing machine>machine; washing machine>pillow; washing machine>pump; washing machine>swimming pool; washing machine>water; wasp>animal; wasp>ant; wasp>bee; wasp>butterfly; wasp>genetics; wasp>hair; wasp>head; wasp>hierarchy; wasp>honey; wasp>insect; wasp>sex; wasp>species; wasp>spider; wasp>spine; waste>awareness; waste>education; waste>litter; waste>material; waste>pollution; waste>recycling; waste>soil; waste>sustainability; waste>university; waste>water; watch>alarm; watch>art; watch>clock; watch>computer; watch>department store; watch>digital camera; watch>gold; watch>temperature; watch>time; watch>video game; water>acid; water>agriculture; water>atmosphere; water>atom; water>bacteria; water>biology; water>body; water>canal; water>carbon dioxide; water>climate; water>cloud; water>coal; water>commerce; water>cooking; water>day; water>density; water>desert; water>diving; water>dna; water>dolphin; water>drought; water>earth; water>energy; water>erosion; water>fire; water>fish; water>flood; water>fog; water>fountain; water>fuel; water>gas; water>gram; water>hall; water>household; water>human; water>hygiene; water>ice; water>ice hockey; water>ice skating; water>iceberg; water>industry; water>kilogram; water>kitchen; water>lake; water>life; water>liquid; water>litre; water>mineral water; water>mist; water>mountain; water>oil; water>oxygen; water>ozone; water>plant; water>politics; water>pollution; water>pond; water>pregnancy; water>protein; water>pump; water>rain; water>rainbow; water>river; water>sea; water>shower; water>sink; water>skiing; water>snow; water>snowboarding; water>soil; water>solution; water>steam; water>stream; water>sugar; water>sun; water>sunlight; water>surfing; water>sweat; water>tide; water>toilet; water>travel; water>valley; water>vegetation; water>whale; water>volcano; waterfall>iceberg; waterfall>volcano; wave>energy; wave>light; wave>momentum; wave>phenomenon; wave>physics; wave>sound; wave>water; wave>violin; wave>x-ray; way>road; weakness>acid; weakness>brain; weakness>nerve; wealth>agriculture; wealth>archaeology; wealth>asset; wealth>building; wealth>business; wealth>castle; wealth>cathedral; wealth>clothing; wealth>economics; wealth>human; wealth>income;

wealth>industrialization; wealth>inheritance; wealth>investment; wealth>leadership; wealth>money; wealth>ownership; wealth>pension; wealth>poverty; wealth>property;
wealth>resource; wealth>soil; wealth>temple; wealth>war; wealth>word; weapon>aircraft; weapon>bracelet; weapon>copper; weapon>crime; weapon>gun; weapon>helicopter;
weapon>horse; weapon>hunting; weapon>knife; weapon>missile; weapon>rocket; weapon>sal; weapon>ship; weapon>sword; weapon>tank; weapon>weather; weather>atmosphere;
weather>building; weather>chemical; weather>climate; weather>climate change; weather>earth; weather>erosion; weather>famine; weather>flood; weather>fog; weather>hail;
weather>heat; weather>ice; weather>lake; weather>plant; weather>potential; weather>snow; weather>storm; weather>sun; weather>sunlight; weather>thunderstorm;
weather>tornado; web page>database; web page>image; web page>website; web page>video; webcam>company; webcam>computer; webcam>daycare; webcam>laptop;
webcam>manufacturing; webcam>microphone; webcam>password; webcam>prison; webcam>time; webcam>web page; website>blog; website>celebrity;
website>computer; website>credit card; website>database; website>document; website>email; website>government; website>image; website>social networking; website>software;
website>stock market; website>web page; website>webcam; wedding>bride; wedding>ceremony; wedding>culture; wedding>divorce; wedding>god; wedding>groom;
wedding>judge; wedding>marriage; wedding>mayor; wedding>mosque; wedding>priest; wedding>ritual; wedding>sibling; wedding>veil; wednesday>calendar; wednesday>fish;
wednesday>meat; wednesday>slang; wednesday>sun; wednesday>thursday; wednesday>tuesday; weed>adaptation; weed>agriculture; weed>crop; weed>garden; weed>grass;
weed>insect; weed>law; weed>park; weed>plant; weed>soil; weed>february; weed>fortnight; week>month; weekday>friday; weekday>monday; weekday>thursday;
weekday>timetable; weekday>tuesday; weekday>wednesday; weekday>week; weekday>weekend; vegetable>acid; vegetable>adjective; vegetable>broccoli; vegetable>bulb;
vegetable>cabbage; vegetable>carrot; vegetable>cereal; vegetable>cooking; vegetable>corn; vegetable>cream; vegetable>cucumber; vegetable>dessert; vegetable>fat;
vegetable>fruit; vegetable>garlic; vegetable>leek; vegetable>lettuce; vegetable>market; vegetable>meal; vegetable>mushroom; vegetable>nutrition; vegetable>onion;
vegetable>peach; vegetable>potato; vegetable>protein; vegetable>purple; vegetable>salt; vegetable>spinach; vegetable>street; vegetable>supermarket; vegetable>tomato;
vegetable>vitamin; vegetation>desert; vegetation>fire; vegetation>flood; vegetation>hierarchy; vegetation>system; vehicle>aircraft; vehicle>bicycle; vehicle>boat; vehicle>brake;
vehicle>bus; vehicle>camel; vehicle>friction; vehicle>fuel; vehicle>machine; vehicle>parachute; vehicle>ship; vehicle>train; vehicle>truck; vehicle>chemistry; weight>ear;
weight>fluid; weight>force; weight>kilogram; weight>matter; weight>momentum; weight>sun; veil>bride; veil>curtain; veil>face; veil>funeral; veil>mask; veil>priest; veil>sail; veil>sin;
veil>tent; veil>turkey; vein>blood; vein>carbon dioxide; vein>heart; vein>laser; vein>lung; vein>oxygen; welfare>debt; welfare>disability; welfare>disaster; welfare>famine;
welfare>household; welfare>illness; welfare>income; welfare>orphan; welfare>pension; welfare>population; welfare>poverty; welfare>salary; welfare>solidarity; welfare>tax;
welfare>unemployment; welfare>veteran; welfare>widow; well-being>economics; well-being>health; velvet>cotton; velvet>linen; velvet>silk; velvet>wool; verb>adverb; verb>clause;
verb>grammar; verb>infinitive; verb>language; verb>phrasal verb; verb>word; verdict>appeal; verdict>judgment; verdict>jury; verdict>law; verse>poetry; west>adjective;
west>adverb; west>death; west>earth; west>east; west>geography; west>hunting; west>liberty; west>north; west>noun; west>south; west>sun; west>water; vet>veteran;
veteran>crisis; veteran>holiday; whale>animal; whale>dolphin; whale>mammal; wheat>bacteria; wheat>beer; wheat>biscuit; wheat>bread; wheat>butterfly; wheat>cake;
wheat>cereal; wheat>cookie; wheat>disease; wheat>fat; wheat>flour; wheat>immune system; wheat>iron; wheat>pancake; wheat>pasta; wheat>pastry; wheat>pie; wheat>protein;
wheat>rice; wheat>tractor; wheat>turkey; wheat>vitamin; wheel>aircraft; wheel>bicycle; wheel>cattle; wheel>energy; wheel>friction; wheel>iron; wheel>iron; wheel>kilogram;
wheel>metre; wheel>pottery; wheel>road; wheel>sphere; wheel>steering wheel; wheel>technology; wheel>tool; wheel>torture; wheel>transport; wheel>truck; wheel>walk;
wheel>wire; wheel>wood; wheelchair>artificial intelligence; wheelchair>bicycle; wheelchair>bus; wheelchair>chair; wheelchair>computer; wheelchair>disability; wheelchair>illness;
wheelchair>revenue; wheelchair>switch; wheelchair>toilet; wheelchair>tram; wheelchair>walking; whim>carriage; whisky>alcohol; whisky>coconut; whisky>corn; whisky>grain;
whisky>linen; whisky>sand; whisky>wheat; whistle>basketball; whistle>dj; whistle>headache; whistle>ice hockey; whistle>jazz; whistle>police; whistle>rhythm; whistle>train;
white>angel; white>autumn; white>black; white>chess; white>cloud; white>coldness; white>cotton; white>crystal; white>density; white>earth; white>frost; white>heat; white>heaven;
white>ice; white>innocence; white>life; white>light; white>peace; white>polar bear; white>racist; white>science; white>snow; white>sunlight; white>swan;
white>tiger; white>toothpaste; white>vinegar; white>winter; white>virtue; vice>alcohol; vice>anger; vice>deputy; vice>envy; vice>faith; vice>gambling; vice>hatred; vice>hope;
vice>jealousy; vice>laziness; vice>pride; vice>sin; vice>vanity; vice>virtue; vice>virtue; vice>aggression; vice>competition; vice>hero; vice>monster; vice>trophy; vice>war; video
clip>advertising; video clip>blog; video clip>celebrity; video clip>digital camera; video clip>icon; video clip>mobile phone; video clip>television; video clip>webcam; video
clip>website; video clip>video; video game>artificial intelligence; video game>distraction; video game>mud; video game>sex; video game>video; video>dvd; video>image;
video>recording; video>technology; video>virtual reality; widow>marriage; widow>orphan; width>length; view>opinion; wife>bride; wife>crime; wife>divorce;
wife>education; wife>female; wife>husband; wife>marriage; wife>mother; wife>mrs; wife>profession; wife>sin; wife>spouse; wife>surname; wife>wedding; wife>widow; wife>woman;
wilderness>camping; wilderness>climate change; wilderness>commerce; wilderness>earth; wilderness>forest; wilderness>genetics; wilderness>geology; wilderness>global
warming; wilderness>human; wilderness>hunting; wilderness>industrialization; wilderness>laboratory; wilderness>law; wilderness>mountain; wilderness>nature;
wilderness>privilege; wilderness>recreation; wilderness>science; wilderness>species; wilderness>summer; wilderness>technology; wilderness>zoo; wildlife>eagle; wildlife>ecology;
wildlife>education; wildlife>extinction; wildlife>feather; wildlife>fishing; wildlife>habitat; wildlife>nature; wildlife>rabbit; wildlife>recreation; wildlife>shark; wildlife>sport; wildlife>tiger;
wildlife>traffic; wildlife>cathedral; village>city; village>community; village>election; village>elite; village>farmer; village>god; village>island; village>market; village>mayor;
village>mosque; village>neighbourhood; village>rice; village>sheep; village>starvation; village>suburb; village>town; villager>newspaper; willingness>will; willpower>self-control;
willpower>self-discipline; wind>victory; wind>aircraft; wind>cattle; wind>civilization; wind>coast; wind>cold; wind>desert; wind>dust; wind>east; wind>electricity; wind>erosion;
wind>fat; wind>feather; wind>friction; wind>history; wind>human; wind>insect; wind>island; wind>kite; wind>landscape; wind>mountain; wind>ocean; wind>penguin; wind>predator;
wind>recreation; wind>runway; wind>sail; wind>sailing; wind>sheep; wind>soil; wind>speed; wind>storm; wind>sun; wind>temperature; wind>thunderstorm; wind>tornado;
wind>transport; wind>water; wind>weather; wind>weed; wind>west; wind>windsurfing; wind>winter; wind>world; wind>aircraft; window>bus; window>curtain; window>door;
window>fire; window>lead; window>paper; window>radiation; window>roof; window>steel; window>wall; window>vehicle; window>wood; windsurfing>helmet; windsurfing>kite;
windsurfing>sail; windsurfing>snowboarding; windsurfing>surfing; wine>acid; wine>archaeologist; wine>beer; wine>cancer; wine>carbon dioxide; wine>carbon footprint;
wine>cucumber; wine>dentist; wine>fence; wine>gardener; wine>grape; wine>grape; wine>litre; wine>oak; wine>plant; wine>plastic; wine>poetry; wine>rice; wine>rose; wine>species;
wine>spice; wine>sugar; wine>sweet; wine>wall; wine>vine; wine>vinegar>apple; wine>vinegar>beer; wine>vinegar>cabbage; wine>vinegar>champagne; wine>vinegar>cholesterol;
vinegar>dessert; vinegar>fever; vinegar>food; vinegar>garlic; vinegar>herb; vinegar>honey; vinegar>onion; vinegar>pear; vinegar>rice; vinegar>spice; vinegar>tomato;
vinegar>water; vinegar>wheat; vinegar>wine; wine>bat; wine>bird; wine>flight; wine>fluid; wine>gas; wine>helicopter; wine>liquid; wine>penguin; wine>physics;
wing>surface; wing>tree; winner>champion; winter>butterfly; winter>global warming; winter>snow; violence>aggression; violence>archaeology; violence>capitalism;
violence>dignity; violence>human rights; violence>interest; violence>law; violence>mammal; violence>murder; violence>neglect; violence>philosophy; violence>police;
violence>pride; violence>psychology; violence>respect; violence>shame; violence>suicide; violence>terrorism; violence>trade; violence>war; violin>arch; violin>cello; violin>disco;
violin>fraud; violin>guitar; violin>horse; violin>jazz; violin>leather; violin>orchestra; violin>piano; violin>rhythm; violin>silk; violin>silver; violin>spectrum; violin>steel; violin>wood;
vires>brass; vires>bronze; vires>cable; vires>copper; wire>diamond; wire>electricity; wire>gold; wire>iron; wire>lead; wire>monopoly; wire>silver; wire>steel; wire>virtual reality>machine;
virtual reality>navy; virtual reality>science fiction; virtual reality>simulation; virtual reality>techno; virtual reality>therapy; virtue>blame; virtue>courage; virtue>courtesy; virtue>dignity;
virtue>discipline; virtue>duty; virtue>faith; virtue>generosity; virtue>goodness; virtue>happiness; virtue>honesty; virtue>hope; virtue>humility; virtue>intelligence; virtue>justice;
virtue>kindness; virtue>law; virtue>love; virtue>loyalty; virtue>mercy; virtue>patience; virtue>peace; virtue>praise; virtue>principle; virtue>psychology; virtue>respect;
virtue>sincerity; virtue>solitude; virtue>sympathy; virtue>truth; virtue>turkey; virtue>vice; virtue>wisdom; virus>antibiotic; virus>animal; virus>cancer; virus>carbon
dioxide; virus>crystal; virus>disease; virus>dna; virus>evolution; virus>genetics; virus>infection; virus>insect; virus>life; virus>plant; virus>poison; virus>protein; virus>species;
virus>vaccination; virus>vaccine; wisdom>analogy; wisdom>artificial intelligence; wisdom>consciousness; wisdom>empathy; wisdom>experience; wisdom>human;
wisdom>ignorance; wisdom>imitation; wisdom>intelligence; wisdom>knowledge; wisdom>memory; wisdom>philosophy; wisdom>poison; wisdom>psychology; wisdom>reflection;
wisdom>science fiction; wisdom>self-awareness; wisdom>sincerity; wisdom>turkey; wisdom>vice; wisdom>virtue; wish>fiction; wish>fountain; wish>goal; wish>common sense;
wit>genius; wit>humour; wit>poetry; wit>reasoning; vitality>health; vitality>life; vitality>youth; vitamin>bone; vitamin>disease; vitamin>fat; vitamin>grain; vitamin>hygiene;
vitamin>lemon; vitamin>liver; vitamin>meat; vitamin>milk; vitamin>moral; vitamin>mouse; vitamin>muscle; vitamin>nutrition; vitamin>protein; vitamin>rat; vitamin>rice; vitamin>salt;
vitamin>skin; vitamin>sunlight; vitamin>surgeon; vitamin>water; withdrawal>anxiety; withdrawal>headache; witness>credibility; witness>judge; witness>lawyer; witness>memory;
witness>prosecution; witness>prosecutor; witness>sense; vocabulary>collocation; vocabulary>communication; vocabulary>education; vocabulary>gesture; vocabulary>infant;
vocabulary>language; vocabulary>learning; vocabulary>speech; volcano>carbon; volcano>carbon dioxide; volcano>carbon monoxide; volcano>chemical; volcano>climate;
volcano>famine; volcano>landscape; volcano>ozone; volcano>planet; volcano>radiation; volcano>soil; volcano>sun; volleyball>basketball; volleyball>tennis; volume>area;
volume>centimetre; volume>circle; volume>density; volume>formula; volume>gas; volume>length; volume>liquid; volume>litre; volume>pin; volume>pressure; volume>quantity;
volume>sphere; volume>teaspoon; volume>weight; woman>adult; woman>beauty; woman>biology; woman>birth; woman>birthday; woman>breast; woman>child; woman>cigarette;
woman>copper; woman>economics; woman>engineering; woman>female; woman>gene; woman>genetics; woman>girl; woman>graduate; woman>health; woman>historian;
woman>human; woman>lady; woman>matter; woman>mirror; woman>professional; woman>psychology; woman>science; woman>spirit; woman>suicide; wood>aluminium;
wood>bark; wood>branch; wood>cherry; wood>coconut; wood>extract; wood>fuel; wood>leaf; wood>oak; wood>pine; wood>root; wood>ski; wood>soil; wood>weapon;
woodland>forest; woodland>grass; wool>auction; wool>carpet; wool>clothing; wool>cotton; wool>leather; wool>linen; wool>preposition; wool>sheep; wool>silk; wool>skin;
word>adjective; word>adverb; word>bear; word>clause; word>grammar; word>language; word>noun; word>noun; word>phrase; word>preposition; words>pronoun; words>pronunciation;
word>speech; word>verb; word>writing; workaholic>alcohol; workaholic>alcoholic; workaholic>stroke; worker>workforce; workforce>employment; workforce>industry;
workforce>management; workforce>wage; workplace>corporation; workplace>employment; workplace>factory; workplace>office; workplace>organization; workshop>aircraft;
workshop>building; workshop>factory; workshop>machine; workshop>manufacturing; workshop>tool; world>career; world>civilization; world>concept; world>consumer;
world>country; world>devil; world>earth; world>experience; world>globalization; world>heaven; world>hell; world>history; world>human; world>paradise; world>planet;
world>population; world>reality; world>region; world>science fiction; world>temptation; worm>animal; worm>corpse; worm>dog; worm>insect; worm>leg; worm>snake; worm>soil;
worm>species; worry>anxiety; worry>emotion; worry>exercise; worry>hug; worry>mind; worry>risk; worry>slump; worship>angel; worship>celebrity; worship>flag; worship>god;
worship>religion; worship>saint; worship>society; worst>superlative; wound>bacteria; wound>bandage; wound>blood; wound>bruise; wound>bruise; wound>infection; wound>injury;
wound>knife; wound>razor; wound>skin; vov>ceremony; vov>meat; vov>promise; vov>wedding; vov>wine; vov>witness; vov>vote; vowel>alphabet; vowel>consonant;
vowel>curtain; vowel>jaw; vowel>language; vowel>preposition; vowel>sound; vowel>syllable; voyage>exploration; voyage>travel; wrinkle>dog; wrinkle>skin; wrinkle>wage;
wrist>hand; writer>actor; writer>argument; writer>astronomy; writer>author; writer>biology; writer>blog; writer>court; writer>culture; writer>dialogue; writer>diary; writer>edition;
writer>education; writer>entertainment; writer>essay; writer>film; writer>fraud; writer>greed; writer>historian; writer>idea; writer>image; writer>irony; writer>literature; writer>logic;
writer>lyrics; writer>narrative; writer>novel; writer>paper; writer>parliament; writer>philosophy; writer>physics; writer>poetry; writer>policy; writer>politics; writer>religion;
writer>revelation; writer>rhyme; writer>rhythm; writer>science fiction; writer>society; writer>writing; writing>alphabet; writing>author; writing>communication; writing>essay;
writing>gerund; writing>history; writing>human; writing>illustration; writing>information; writing>journalism; writing>journalist; writing>language; writing>literacy; writing>literature;
writing>novelist; writing>painting; writing>paper; writing>pen; writing>pencil; writing>poet; writing>science; writing>syllable; writing>time; writing>translation; writing>writer;
xenophobia>concept; xenophobia>culture; xenophobia>imitation; xenophobia>immigration; xenophobia>individual; xenophobia>prejudice; xenophobia>propaganda;
xenophobia>racism; xenophobia>society; x-ray>aluminium; x-ray>astronomy; x-ray>bone; x-ray>cancer; x-ray>copper; x-ray>dna; x-ray>energy; x-ray>experiment; x-ray>iron; x-
ray>kilogram; x-ray>life; x-ray>muscle; x-ray>surgeon; yacht>air conditioning; yacht>aluminium; yacht>boat; yacht>cargo; yacht>customs; yacht>radio; yacht>sailing; yacht>ship;
yacht>steel; yacht>tide; yard>area; yard>golf; yard>inch; yard>length; yard>metre; yard>volume; year>archaeology; year>astronomy; year>autumn; year>calendar; year>day;
year>daylight; year>dinosaur; year>earth; year>geology; year>hour; year>millennium; year>minute; year>month; year>pie; year>planet; year>season; year>second; year>summer;
year>sun; year>time; year>weather; year>week; year>vegetation; year>winter; yellow>autumn; yellow>bee; yellow>bus; yellow>butter; yellow>coward; yellow>curiosity;
yellow>daylight; yellow>electricity; yellow>envy; yellow>friendship; yellow>gold; yellow>green; yellow>hope; yellow>imagination; yellow>intellectual; yellow>jam; yellow>jealousy;
yellow>laser; yellow>lemon; yellow>mirror; yellow>optimism; yellow>rebellion; yellow>recreation; yellow>rose; yellow>spectrum; yellow>spice; yellow>star; yellow>sugar;
yellow>summer; yellow>sun; yellow>sunshine; yellow>temperature; yellow>traffic light; yellow>wasp; yellow>water; yellow>vein; yoqa>mind; yoqa>soul; yoqa>stroke;

yogurt>bacteria; yogurt>bakery; yogurt>camel; yogurt>cherry; yogurt>cucumber; yogurt>farmer; yogurt>fast food; yogurt>fat; yogurt>fruit; yogurt>garlic; yogurt>goat; yogurt>honey; yogurt>jam; yogurt>mango; yogurt>milk; yogurt>olive; yogurt>onion; yogurt>peach; yogurt>pineapple; yogurt>protein; yogurt>salt; yogurt>sheep; yogurt>spinach; yogurt>strawberry; yogurt>sugar; yogurt>turkey; youngster>child; youth>adult; youth>childhood; youth>obesity; youth>suicide; zebra>animal; zebra>donkey; zebra>extinction; zebra>hill; zebra>horse; zebra>mammal; zebra>mountain; zebra>species; zebra>woodland; zone>tv; zoo>bird; zoo>chicken; zoo>ecology; zoo>elephant; zoo>extinction; zoo>fish; zoo>giraffe; zoo>insect; zoo>mammal; zoo>neglect; zoo>reptile; zoo>species; zoo>whale;

Appendix AD

As discussed in Subchapter 12.2, this listing shows in respect to English Vocabulary Profile for each vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each language ability level. For each observed vocabulary ranging from A1 to A1&A2&B1&B2&C1&C2 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from A1 to A1&A2&B1&B2&C1&C2.

In contrast with Appendix AE, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

Among 2878 unique concepts the biggest subentity that enabled traversing hyperlink chains between any of concepts belonging to this subentity in hyperlink network of vocabulary A1&A2&B1&B2&C1&C2 when any hyperlink can be traversed in both actual linking direction and opposite direction contained 2850 unique concepts and 28 external unique concepts include: comment, direction, directions, end, ending, exhaust, exhaustion, hole, network, networking, northwest, opening, program, programme, register, registration, remark, resemblance, scene, scenery, similarity, southeast, superior, superiority, term, terms, will and willingness.

<p>Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1 (i.e. when range of language ability levels reached so far is A1)</p> <p><i>Alltogether 248 nouns with the following subdivision.</i></p> <p><i>Nouns belonging to language ability level A1 (248 nouns):</i> adult; afternoon; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; body; book; box; boy; bread; breakfast; bus; business; butter; café; cake; camera; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; coat; coffee; colour; computer; conversation; country; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; door; dress; drink; dvd; ear; email; evening; eye; face; factory; family; farm; father; february; film; fish; floor; flower; food; foot; football; friday; friend; fruit; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; kitchen; knife; language; leg; lesson; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mrs; mum; museum; music; nationality; newspaper; night; noise; nose; note; november; number; october; paint; paper; parent; park; party; pen; pencil; people; person; pet; picnic; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; skirt; smoking; snow; son; soup; sport; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; thursday; time; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;</p> <p><i>Nouns belonging to language ability level A2 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level B1 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level B2 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level C1 (0 nouns):</i> No nouns.</p> <p><i>Nouns belonging to language ability level C2 (0 nouns):</i> No nouns.</p>
<p>Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2 (i.e. when range of language ability levels reached so far is A1–A2)</p> <p><i>Alltogether 706 nouns with the following subdivision.</i></p> <p><i>Nouns belonging to language ability level A1 (265 nouns):</i> adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans;</p>

juice; july; june; kitchen; knife; language; leg; lesson; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; party; pen; pencil; people; person; pet; phone; photo; picnic; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (441 nouns):

accident; actor; adjective; adverb; advertisement; air; airport; alarm clock; album; alcohol; ambulance; apartment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; bottle; bowl; boyfriend; brain; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; chat; chef; chemist; chemistry; cheque; chess; chicken; cigarette; circle; cleaner; climbing; cloud; clown; club; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; island; jam; jazz; jewellery; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; mail; main course; make-up; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; perfume; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; stage; stairs; star; steak; stomach; storm; suitcase; sunglasses; superlative; supper; surfing; surname; sweet; sweets; table tennis; team; teenager; telephone; temperature; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour guide; tourist; towel; toy; traffic; traffic light; tram; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (0 nouns):

No nouns.

Nouns belonging to language ability level B2 (0 nouns):

No nouns.

Nouns belonging to language ability level C1 (0 nouns):

No nouns.

Nouns belonging to language ability level C2 (0 nouns):

No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1 (i.e. when range of language ability levels reached so far is A1–B1)

Alltogether 1374 nouns with the following subdivision.

Nouns belonging to language ability level A1 (273 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; fish; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; party; pen; pencil; people; person; pet; phone; photo; picnic; pig; pizza; plant; player; potato; problem; question; radio; rain; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (465 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; bottle; bowl; boyfriend; brain; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; lugg; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; perfume; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (636 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; bull; bulk; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collection; comedy; comma; common sense; communication; competitor; complaint; conclusion; conference; consonant; contest; contamine; contract; corn; cottage; cotton; cough; count; courgette; count; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cyclist; death; definite article; demand; description; design; designer; destination; detective; diagram; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; dust; dustbin; duty; duvet; earth; economics; education; effect; effort; elbow; election; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; essay; event; exchange; exchange rate; excitement; exhibition; experience; experiment; expert; explanation; extreme sports; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; figure; fiction; figure; fire station; firefighter; fireworks; firm; flag; flood; flour; flute; fly; folk; food; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; heart attack; heat; heater; heel; height; herb; hero; honeymoon; hope; host; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; membership; mess; message board; metal; mile; millimetre; mind; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; olive; opinion; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; password; patient; pattern; pay; pea; peace; peach; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy;

photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; relation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; return; review; robot; role; roll; rose; rubbish; rug; rule; run; sailor; salary; salmon; sand; sandal; saucer; scene; scenery; science fiction; scientist; sculpture; season; secondary school; secret; security; seller; sense; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; silence; silk; ski; sir; skill; skin; sleep; sleeve; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spice; spider; spinach; spy; statue; step; stick; stone; strawberry; stream; strike; studio; study; style; success; sunrise; sunset; sunshine; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thought; throat; thumb; thunder; tick; tiger; tin; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; unit; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windscreen; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (0 nouns):
No nouns.

Nouns belonging to language ability level C1 (0 nouns):
No nouns.

Nouns belonging to language ability level C2 (0 nouns):
No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2 (i.e. when range of language ability levels reached so far is A1–B2)

Alltogether 2121 nouns with the following subdivision.

Nouns belonging to language ability level A1 (280 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (473 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; clear; climbing; cloud; clown; club; coach; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast; food; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pence; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; pupil; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; purple; pulse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; store; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; term; text; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; yellow; yogurt;

Nouns belonging to language ability level B1 (682 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; captain; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; demand; description; design; designer; destination; detective; diagram; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earth; economics; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; equipment; essay; event; exchange; exchange rate; excitement; exhibition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; figure; fire station; firefighter; firework; firm; flag; flood; flour; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hole; honeymoon; hope; hostel; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; mind; minimum; mix; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; olive; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; password; patient; pattern; pay; pea; peace; peach; peak; peanut; pedestrian; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; relation; relaxation; remote control; repair; reply; report; reporter; request; rescue; research; resort; score; result; result; return; reward; review; robot; role; roll; rose; rubbish; rug; rule; run; sailor; salary; salmon; sand; sandal; saucer; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; silence; silk; ski; ski; skill; skin; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spider; spinach; spy; statue; step; stick; stone; strawberry; stream; strike; studio; study; style; suggestion; sun; sunrise; sunset; sunshine; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thief; thought; throat; thumb; thunder; tick; tiger; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windscreen; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (686 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; atom; attachment; attempt; authority; availability; award; backup; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breed; brick; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; chart; chemical; cherry; chest; chimney; choir; citizen; civilization; claim; classic; clause; client; climate

change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confidence; confirmation; confusion; consciousness; consequence; consideration; construction; consultant; consumer; container; content; contribution; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; eraser; escalator; estate; evidence; evil; evolution; exclamation mark; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fault; feather; feedback; female; fence; finance; fingernail; first language; fisherman; flame; flash; fluency; force; fortune; fox; freedom; frost; frustration; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graduate; graph; grave; greatness; grief; growth; guarantee; guidance; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; honesty; honour; horn; host; household; human rights; humour; hunting; hyphen; icon; idiom; idiot; image; immigrant; income; independence; individual; infection; inflation; injury; input; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; invasion; inventor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leak; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; loaf; loss; loyalty; lung; lyrics; majority; male; management; mankind; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; microphone; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience; pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; poison; polar bear; policy; politeness; pond; popularity; portrait; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; production; professional; proof; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punishment; quarrel; query; quiet; racism; rage; rainbow; rape; rate; razor; reach; reality; recession; recovery; recreation; referee; reference; reflection; refugee; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush hour; sadness; safety; satellite; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shooting; shopkeeper; shot; sickness; signal; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storey; strategy; strength; string; stroke; structure; substance; suburb; suffering; suffix; sun; sunlight; supplier; surface; surgery; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; target; task; teaspoon; telecommunications; telescope; temper; temptation; terms; terrace; terror; terrorism; terrorist; theft; theory; therapy; thermometer; thesis; thigh; thirst; threat; tide; timing; toenail; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; trophy; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (0 nouns):

No nouns.

Nouns belonging to language ability level C2 (0 nouns):

No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2&C1 (i.e. when range of language ability levels reached so far is A1–C1)

Alltogether 2470 nouns with the following subdivision.

Nouns belonging to language ability level A1 (281 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; decorate; desk; dictionary; dining room; dinner; doctor; dog; doll; dollar; door; dress; drink; dvd; ear; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fun; fruit; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (479 nouns):

accident; actor; adjective; adventure; adverb; advertisement; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; bread; bridge; brown; brush; building; bus station; bus; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; castle; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chess; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; cricket; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; dreaming; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; field; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandpa; grandmother; grandparent; grandson; granny; grape; green; grey; guide; hall; ham; handbag; headache; health; heart; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; mail; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory; menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pence; perfume; petrol; petrol station; photograph; photographer; photography; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; pop; post; post office; postcard; poster; present; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; roof; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; sink; site; sitting room; size; skate; skateboarding; skating; skiing; ski; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; type; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Nouns belonging to language ability level B1 (694 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; canal; cancer; candidate; candle; captain; care; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; cheque; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; demand; description; design; designer; destination; detective; diagram; diet; difficulty; direction; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; dust; duty; duvet; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; ending; enemy; energy; engineering; enquiry; entertainment; equipment; essay; event; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; figure; fire station; firefighter; firework; firm; flag; flood; flour; flu; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hole; honeymoon; hope; hostel; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; improvement; inch; indefinite article; industry; infinitive; inordinate; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; milk; minimum; mix; monster; monument; mosquito; moustache; murder; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northwest; novel; object; ocean; officer; olive; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; password; patient; pattern; pay; pea; peace; peach; peak; peanut; pedestrian; penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess;

prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; question mark; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; registration; relation; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; return; reward; robot; role; roll; rose; row; rubbish; rug; rule; run; sailor; salary; salesman; salmon; sand; sandal; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shopping; signature; silence; silk; skill; skin; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spice; spider; spinach; spy; statue; step; stick; stone; store; strawberry; stream; strike; studio; study; style; success; suggestion; sun; sunrise; sunset; sunshine; support; supporter; sweatshirt; switch; system; talent; talk; taste; tax; teaching; technique; temple; tent; thief; thought; throat; thumb; thunder; tick; tiger; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; unicorn; uncountable; underwear; unemployment; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; whale; wheelchair; video clip; wildlife; windscreens; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (701 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; assistance; atom; attachment; attempt; authority; availability; award; backup; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breakthrough; breed; brick; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; chart; chemical; cherry; chest; chimney; choir; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; combination; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confidence; confirmation; confusion; consciousness; consequence; consideration; construction; consultant; consumer; container; content; contribution; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; bed; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; error; escalator; estate; evidence; evil; evolution; exclamation mark; exhaustion; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fate; fault; feather; feedback; female; fence; finance; fingernail; first language; fisherman; flame; flash; fluency; force; fortune; fox; freedom; frost; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graduate; graph; grave; greatness; grief; growth; guarantee; guidance; guilt; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; honesty; honour; horn; host; household; human rights; humour; hunting; hyphen; icon; idiom; idiot; inventor; immigrant; income; independence; individual; infection; inflation; injury; input; inspector; inspiration; institute; insult; insurance; intelligence; intention; invasion; investor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leak; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; loaf; loss; loyalty; lung; lyrics; majority; male; management; mankind; manual; manufacturing; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; microphone; mine; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; network; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience; pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pint; pitch; pity; planning; plot; plumber; poison; polar bear; policy; politeness; pond; popularity; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; production; professional; proof; proposal; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punishment; quarrel; query; quiet; racism; rage; rainbow; rape; rate; razor; reach; reality; rebel; recession; recovery; recreation; referee; reference; reflection; refuge; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; risk; rise; robbery; rocket; roommate; root; rope; rumour; rush hour; sadness; safety; satellite; savings; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shooting; shopkeeper; shop; sickness; signal; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storey; strategy; strength; string; stroke; structure; substance; suburb; suffering; suffix; suicide; sunlight; supplier; surface; surgery; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; target; task; teaspoon; telecommunications; telescope; temper; temptation; terminal; terms; terrace; terror; terrorism; terrorist; theft; theme; theory; therapy; thermometer; thesis; thigh; thirt; threat; tide; timing; toennal; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; trophy; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; wheat; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (315 nouns):

abortion; acceptance; adaptation; administration; aggression; aid; allegation; allowance; amateur; amendment; angle; annoyance; appetite; applause; archaeologist; archaeology; asset; assumption; assurance; auction; audition; awareness; bacteria; beak; blindness; boundary; brass; bribe; bronze; campaign; carriage; cholesterol; clutch; coal; collaboration; commodity; competence; complex; component; consent; constitution; consumption; contestant; controversy; corruption; coverage; cultivation; daycare; dedication; deficiency; delegate; density; deodorant; destiny; diesel; digestion; discomfort; discrimination; disorder; disrespect; disruption; dissertation; distraction; distress; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; erosion; establishment; evaluation; exaggeration; exhaust; exhibit; expenses; exploration; exposure; extinction; fabric; fairness; feast; fibre; formula; friction; fright; fund; funding; gadget; gain; garment; gene; generalization; genius; geology; gerund; gesture; globalization; greed; habitat; harassment; hate; hatred; hazard; heading; health care; historian; hospitality; housing; humanity; hygiene; iceberg; illustration; import; indication; industrialization; infrastructure; injustice; innocence; innovation; insight; inspection; installation; interaction; isolation; itinerary; jargon; jealous; joint; journal; junk; knob; labour; landmark; launch; lawn; leadership; liability; limitation; literacy; log; logic; loneliness; lounge; machinery; magistrate; mammal; mansion; mat; mechanism; miner; mining; mode; move; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; nutrition; obesity; obstacle; occurrence; odds; organ; overdraft; ownership; ozone; park; paradise; pastry; peasant; pensioner; perfection; personell; phenomenon; pony; praise; predator; pregnancy; premises; principle; privilege; probability; productivity; programmer; progression; proposition; prosperity; prostitute; protein; provider; pulse; pyramid; radiation; rating; ratio; rebellion; recruitment; rectangle; redevelopment; register; reign; relevance; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rival; role model; rudeness; sack; sacrifice; saint; saving; scholar; sector; self; self-esteem; selfishness; sequence; serial; setback; sewing; shame; shuttle; shyness; side effect; simplicity; simulation; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; spam; specification; spectrum; speculation; sphere; spokesman; spokesperson; sponsorship; staircase; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; strip; subsidy; subtitles; successor; summit; supervision; supervisor; surgeon; takeover; tank; teamwork; technician; techno; telly; therapist; tobacco; torture; trainee; transportation; trek; tuition; turnover; uncertainty; usage; walker; warrior; vegetation; veil; vein; well-being; vest; win; vine; wit; witch; workforce; workplace; workshop; youngster;

Nouns belonging to language ability level C2 (0 nouns):

No nouns.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of A1&A2&B1&B2&C1&C2 (i.e. when range of language ability levels reached so far is A1-C2)

Alltogether 2878 nouns with the following subdivision.

Nouns belonging to language ability level A1 (283 nouns):

adult; afternoon; age; animal; answer; apple; april; arm; august; baby; bag; ball; banana; band; bank; basketball; bathroom; beach; beard; bed; bedroom; beer; bird; birthday; biscuit; board; boat; body; book; bottom; box; boy; bread; breakfast; brother; bus; business; butter; café; cake; camera; car; cat; cd; cd player; chair; cheese; child; chip; chocolate; city; class; classroom; clock; clothes; coat; coffee; colour; computer; conversation; country; course; cow; credit card; cross; cup; dad; dance; dancing; daughter; day; december; desk; dictionary; dining room; dinner; doctor; dog; doll; dollar; door; dress; drink; dvd; end; email; end; evening; eye; face; factory; family; farm; father; february; film; fish; flat; floor; flower; food; foot; football; friday; friend; fruit; fun; game; garden; girl; glass; glasses; grass; group; guitar; hair; hand; hat; head; holiday; home; homework; horse; hospital; hotel; hour; house; husband; ice cream; jacket; january; jeans; juice; july; june; key; kind; kitchen; knife; language; leg; lesson; letter; life; living room; lunch; man; march; may; meal; meat; message; milk; minute; miss; mobile; mobile phone; monday; money; month; morning; mother; mouth; movie; mr; mrs; mum; museum; music; name; nationality; newspaper; night; noise; nose; note; november; number; number; october; page; paint; pair; paper; parent; park; part; party; pen; pencil; people; person; pet; phone; photo; picnic; picture; pig; pizza; place; plant; player; potato; problem; question; radio; rain; reading; restaurant; rice; river; road; room; salt; sandwich; saturday; school; sea; september; sheep; shirt; shoe; shop; shopping; shower; sister; skirt; smoking; snow; son; soup; sport; station; stop; street; student; sugar; summer; sun; sunday; supermarket; swimming pool; tea; teacher; television; tennis; test; the internet; thursday; time; today; toilet; tomato; tooth; town; train; tree; trousers; t-shirt; tuesday; tv; university; waiter; wall; watch; water; weather; website; wednesday; week; weekend; vegetable; wife; village; wind; window; wine; winter; woman; word; world; writing; year; zoo;

Nouns belonging to language ability level A2 (483 nouns):

accident; actor; adjective; adventure; advb; advertisement; advice; aeroplane; air; airport; alarm clock; album; alcohol; ambulance; apartment; appointment; area; art; artist; aunt; autumn; back; badminton; balloon; barbecue; baseball; bat; bean; bear; bicycle; bike; bill; biology; bit; black; blackboard; blanket; blood; blue; board game; bookcase; bookshelf; boot; boss; bottle; bowl; boyfriend; brain; break; bridge; brown; brush; building; bus station; bus stop; calendar; camping; can; cap; capital; capital letter; car park; card; carpet; carrot; cartoon; case; cash; cask; cathedral; ceiling; cent; centimetre; century; cereal; chain; champagne; change; channel; chat; chef; chemist; chemistry; cheque; chick; chicken; church; cigarette; circle; cleaner; click; climbing; cloud; clown; club; coach; cola; cold; colleague; college; comb; comic; company; comparative; competition; concert; cook; cooking; cost; cousin; cream; creak; crowd; cupboard; curry; curtain; customer; cycling; dancer; danger; degree; dentist; department; department store; desert; dessert; diary; digital camera; dinosaur; diploma; directions; disco; document; drawer; drawing; dream; drum; duck; earring; east; electricity; elephant; engine; engineer; entrance; envelope; euro; exam; examination; exercise; exit; fact; farmer; fashion; fast food; field; finger; fire; fishing; flight; fog; forest; fork; form; furniture; garlic; gas; gate; geography; gift; girlfriend; glove; goal; gold; golf; gram; grammar; grandchild; granddad; granddaughter; grandfather; grandma; grandmother; grandpa; grandparent; grandson; granny; grape; green; grey; guest; guide; hall; ham; handbag; headache; health; heat; heating; helicopter; help; hill; hip-hop; history; hobby; hockey; honey; housewife; ice; id card; idea; information; insect; insect; instrument; island; jam; jazz; jewellery; journey; jumper; kick; kid; kilo; kilogram; kilometre; king; kiss; kit; kite; lake; laptop; leather; lemon; lemonade; level; library; light; line; lion; litre; luck; luggage; lunchtime; machine; magazine; magic; mail; main course; make-up; manager; mango; map; mark; market; match; mechanic; medicine; meeting; melon; member; memory;

menu; metre; midday; midnight; mineral water; mirror; model; monkey; mosque; motorway; mountain; mouse; mp3 player; mug; mushroom; nature; neck; necklace; news; noon; north; notebook; notice; noun; nurse; occupation; office; oil; omelette; onion; opera; order; pain; painter; painting; partner; passenger; passport; pasta; pc; pear; pencil; perfume; petrol; petrol station; photograph; photographer; physics; piano; piece; pillow; pink; plan; plastic; playground; plural; pocket; police; police officer; police station; policeman; policewoman; pool; post; post office; postcard; poster; present; price; prize; program; programme; project; pub; pupil; purple; purse; puzzle; quiz; rabbit; railway; raincoat; rat; reason; receipt; receptionist; red; rest; right; rock; rock; roundabout; rubber; rugby; ruler; runner; running; sailing; salad; sauce; sausage; scarf; schoolchild; science; scissors; screen; seat; second; secretary; set; shampoo; ship; shorts; show; side; sightseeing; sign; silver; singer; singing; singular; sink; site; sitting room; size; skate; skateboard; skateboarding; skating; skiing; sky; snack; snake; snowboarding; soap; sock; soft drink; software; song; soul; sound; south; space; spelling; spoon; square; stadium; staff; stage; stairs; star; steak; stomach; storm; story; suitcase; sunglasses; superlative; supper; surfing; surname; sweater; sweet; sweets; table tennis; team; teenager; telephone; temperature; term; text; text message; textbook; theatre; thunderstorm; tights; timetable; toast; toe; toothache; toothbrush; top; tour; tour guide; tourist; towel; toy; traffic; traffic light; tram; trip; tune; type; umbrella; uncle; uniform; walk; walking; wallet; war; washing machine; way; web page; weekday; verb; west; wheel; white; video; video game; view; winner; violin; vocabulary; volleyball; wood; wool; worker; yellow; yogurt;

Nouns belonging to language ability level B1 (706 nouns):

ability; accent; account; accountant; ache; act; action; ad; advantage; advert; air conditioning; air force; airline; alarm; alphabet; amount; angel; animation; ankle; anniversary; ant; antique; application; architect; architecture; argument; arrangement; aspirin; athletics; atmosphere; attention; audience; author; average; background; backpack; backpacker; backpacking; bacon; baggage; baker; balcony; ballet; bandage; bank account; barber; basket; battle; bay; beauty; bee; beef; behaviour; benefit; bin; biography; birth; blog; blogger; bomb; bone; booking; border; boxing; bracelet; brake; branch; breast; breath; breeze; bride; broccoli; brochure; bucket; bug; bull; bunch; butcher; butterfly; button; buyer; cabbage; cabin; cable; calculator; calf; camel; camp; campsite; cancer; candidate; candle; captain; care; career; cattle; cave; cd-rom; celebration; celebrity; central heating; ceremony; challenge; champion; championship; chance; charge; check; cheek; chest of drawers; chewing gum; childhood; chin; choice; circus; cliff; climate; clinic; coast; coconut; cod; coin; collar; collection; comedy; comma; comment; common sense; communication; competitor; complaint; conclusion; conference; consonant; contents; contest; continent; contract; corn; correction; cottage; cotton; cough; count; courgette; court; crash; creature; credit; crew; crime; criminal; crop; cucumber; culture; currency; curriculum; cushion; custom; customs; cut; cv; cyclist; damage; death; decision; defeat; definite article; delivery; demand; description; design; designer; destination; detail; detective; diagram; diet; difficulty; directions; dirt; disadvantage; disappointment; disc; disc jockey; discussion; disease; dishwasher; disk; distance; district; diver; diving; divorce; dj; documentary; dolphin; donkey; dot; doubt; download; drama; drive; drop; dust; dustbin; duty; duvet; earth; economics; edge; education; effect; effort; elbow; election; embassy; emergency; employee; employer; employment; enemy; energy; engineering; enquiry; entertainment; equipment; enquiry; essay; event; exchange; exchange rate; excitement; excuse; exhibition; expedition; experience; experiment; expert; explanation; extreme sports; facilities; fair; fall; fare; farming; favourite; fear; fee; feeling; ferry; festival; fever; fiction; fight; figure; fire station; firefighter; firework; firm; flag; flood; flu; flute; fly; folk; fool; forehead; fortnight; fountain; frame; freezer; friendship; frog; frying pan; fuel; full stop; fur; future; gallery; generation; ghost; giraffe; goalkeeper; goat; government; graphics; greeting; grill; groom; ground; guard; guitarist; gun; gym; gymnastics; habit; haircut; hairdresser; handkerchief; handwriting; happiness; harbour; hardware; headline; heart attack; heat; heater; heel; height; herb; hero; hole; honeymoon; hope; hostel; housework; hug; human; hunger; ice hockey; ice skating; illness; imagination; immigration; importance; improvement; inch; indefinite article; industry; infinitive; ingredient; initial; ink; inquiry; instructor; interest; interview; invention; iron; ironing; issue; jail; jar; jogging; joke; journalist; judge; jug; jump; jungle; kangaroo; keeper; kettle; killer; killing; kitten; knee; knowledge; lab; label; laboratory; ladder; lady; lamb; land; landscape; laugh; law; lawyer; leader; leaf; lecture; leisure; length; lettuce; lie; lighter; lightning; link; lip; liquid; literature; loan; logo; lorry; lottery; love; lover; madam; marriage; material; meaning; membership; mess; message board; metal; mile; millimetre; mind; minimum; milk; monster; monument; mosquito; moustache; murderer; musician; mystery; neighbourhood; nephew; niece; nightclub; nightlife; nightmare; northeast; northwest; novel; object; ocean; officer; olive; operation; opinion; opportunity; opposite; orchestra; organization; oven; owner; palace; pan; pants; paragraph; parcel; parking; parrot; passport; patient; pattern; pay; pea; peace; peach; peak; peanut; pedestrian; Penguin; penny; performance; performer; period; pharmacy; photocopy; phrasal verb; phrase; pie; pin; pineapple; pirate; planet; pleasure; poem; poet; poetry; point; politician; politics; pollution; population; pork; port; possibility; pot; prayer; preparation; preposition; presentation; president; priest; primary school; prince; princess; prison; prisoner; profession; professor; promise; pronoun; pronunciation; property; public transport; pullover; pump; punctuation; puppy; purpose; push; qualification; quantity; questionnaire; rail; rainforest; reception; recipe; record; recording; recycling; refund; region; registration; relation; relaxation; religion; remote control; repair; reply; report; reporter; request; rescue; research; resort; respect; result; return; reward; review; robot; role; roll; rose; row; rubbish; rug; rule; run; sailor; salary; salesman; salmon; sand; sandal; saucepan; saucer; scene; scenery; science fiction; scientist; score; sculpture; season; secondary school; secret; security; seller; sense; series; sex; shade; shadow; shape; shark; sheet; shore; shoulder; signature; signpost; silence; silk; single; sir; ski; skill; sleep; sleeve; smell; smile; smoke; snowboard; soap opera; social networking; society; soldier; solution; southeast; souvenir; speech; speed; spider; spinach; spy; stall; statue; step; stick; stone; store; strawberry; stream; strike; studio; student; style; success; suggestion; sun; sunrise; sunset; sunshine; support; supporter; sweatshirt; switch; system; tablet; talent; talk; taste; tax; teaching; technique; technology; temple; tent; thief; thought; throat; thumb; thunder; tin; tip; title; tongue; toothpaste; tourism; tournament; tower; track; tracksuit; trade; traffic jam; training; translation; transport; travel; travel agent; trend; trouble; truck; trumpet; tube; tuna; tunnel; turkey; turn; turning; twin; uncountable; underpants; underwear; unemployment; union; unit; user; wage; valley; van; wardrobe; vase; waste; waterfall; wave; weather forecast; webcam; wedding; vegetarian; vehicle; weight; vet; whale; wheelchair; video clip; wildlife; windscreens; windsurfing; wing; virus; volume; worry; worst; vote; vowel; writer; yard; yoga; youth; zone;

Nouns belonging to language ability level B2 (718 nouns):

abuse; accuracy; acid; addict; addiction; addition; admiration; adoption; advertising; affair; affection; agent; agreement; agriculture; aircraft; aluminium; ambassador; amusement; analysis; ancestor; anger; anxiety; apostrophe; appeal; arrest; arrow; assistance; atom; attachment; attempt; authority; availability; award; badge; bakery; bang; banker; banking; bargain; barrier; basement; belief; bench; berry; bestseller; bikini; bite; blade; blame; bomber; bombing; bond; booklet; bookmark; boost; bow; bracket; brand; bravery; breakthrough; breed; bred; broadband; brother-in-law; bruise; budget; bulb; bullet; bun; burglar; burglary; calculation; campus; capacity; carbon; carbon dioxide; carbon footprint; carbon monoxide; carelessness; carnival; cast; catering; cause; cell; cellar; cello; cemetery; certainty; characteristic; charm; chart; chemical; cherry; chess; chimney; choir; citizen; civilization; claim; classic; clause; client; climate change; cloth; clothing; clue; coaching; code; coincidence; collocation; column; combination; comedian; comfort; commerce; commercial; commitment; committee; community; companion; composer; compromise; concentration; concept; concern; concrete; confession; confidence; confirmation; conflict; confusion; consciousness; consequence; conservation; consideration; construction; consultant; consumer; container; content; contribution; control; convenience; cooperation; copper; corporation; corridor; costume; council; counter; county; courage; courtesy; coward; crab; craft; creation; creativity; crisis; critic; criticism; crocodile; cruelty; cure; curiosity; curve; cycle; darkness; dash; data; database; dawn; daylight; deal; debate; debit; debit card; debt; decade; deck; decline; decoration; deer; definition; delight; democracy; denim; desire; desktop; determination; determiner; device; devil; dialogue; diamond; dilemma; dimension; diplomat; disability; disagreement; disaster; discipline; disguise; dishonesty; dislike; distinction; dive; donation; dose; draft; drug; eagerness; eagle; earnings; earthquake; economist; economy; edition; efficiency; electrician; electronics; element; embarrassment; emotion; enjoyment; entertainer; enthusiasm; environment; envy; episode; equal; era; error; escalator; estate; evidence; evil; evolution; exclamation mark; exhaustion; existence; expense; explosion; export; extract; eyebrow; eyelash; eyelid; eyesight; facility; failure; faith; fame; fantasy; fat; fate; fault; feather; feedback; female; fence; fighting; finance; fingernail; first language; fisherman; flame; flash; fluency; force; fortune; fox; freedom; frost; frustration; function; funeral; gambling; gang; gardener; gardening; gear; gender; generosity; genetics; gentleman; global warming; god; gossip; graduate; graph; grave; greatness; grief; growth; guarantee; guidance; guilt; gum; hammer; handle; handout; hard drive; harm; harmony; harvest; headquarters; heaven; hedge; hell; helmet; hip; hold; honesty; honour; horn; host; household; human rights; humour; hunting; hyphen; icon; identity; idiom; idiot; image; immigrant; income; independence; individual; infection; inflation; injury; input; inspector; inspiration; institute; institution; insult; insurance; intelligence; intention; invasion; inventor; investigation; investigator; investment; investor; jaw; jewel; journalism; joy; judgment; junk food; jury; justice; kindness; kingdom; landing; landlady; landlord; lane; lap; laser; laughter; laundry; laziness; lead; leaflet; leak; learner; learning; lecturer; leak; legend; leopard; liar; liberty; lid; lighting; litter; liver; living; load; loaf; loss; loyalty; lung; lyrics; majority; male; management; mankind; manual; manufacturer; manufacturing; marathon; marketing; martial art; mask; master; matter; mayor; measure; measurement; medal; mention; microphone; mine; minority; miracle; misery; mist; misunderstanding; mixture; moonlight; motivation; motive; motor; motorist; mud; muscle; musical; myth; nation; native speaker; navy; need; nerves; network; nonsense; novelist; nuisance; oak; obligation; observation; opening; origin; overtime; owl; oxygen; pace; pack; pancake; panic; parachute; parade; parliament; partnership; passage; patience; pause; paw; payment; penalty; pension; percentage; personality; pharmacist; philosopher; philosophy; pine; pin; pitch; pity; planning; plot; plumber; poison; polar bear; policy; politeness; pond; popularity; portrait; possession; potential; pottery; poverty; prawn; prediction; preference; prefix; prejudice; presenter; presidency; pressure; prevention; pride; prime minister; principal; priority; privacy; procedure; professional; proof; proposal; protection; protest; psychologist; psychology; publication; publicity; publisher; pudding; punishment; quarrel; query; quiet; racism; rage; rainbow; rape; rate; razor; reach; reality; rebel; recession; recovery; recreation; referee; reference; reflection; refugee; regulation; rehearsal; relief; remains; remark; remedy; reputation; requirement; researcher; reserve; resident; resource; response; responsibility; retirement; revenge; revolution; rhythm; rib; rise; risk; robbery; rocket; roommate; root; rope; rumour; rush hour; sadness; safety; satellite; savings; scandal; scar; scent; scratch; seed; selection; self-confidence; semicolon; seminar; sensation; servant; setting; shed; shelter; shooting; shopkeeper; shot; sickness; signal; similarity; sister-in-law; skeleton; slave; slope; smoker; soil; soundtrack; source; specialist; species; spirit; spread; spreadsheet; stain; standard; state; statistics; steam; steel; steering wheel; stepmother; stock; storage; storey; strategy; strength; string; stroke; structure; substance; suburb; suffering; suffix; suicide; sunlight; supplier; surface; surgery; surroundings; survey; survival; suspect; swan; sweat; sword; syllable; symbol; sympathy; symptom; tail; tale; target; task; teaspoon; telecommunications; telescope; temper; temptation; tension; terminal; terms; terrace; terror; terrorism; terrorist; theft; theme; theory; therapy; thermometer; thesis; thigh; thirst; threat; tide; toenal; tomb; ton; tone; tool; torch; tornado; touch; trace; tradition; tragedy; trail; tray; treasure; treatment; trekking; trial; triangle; tribe; trophy; truth; try; tutor; understanding; unhappiness; upgrade; waist; ward; warmth; wasp; weakness; wealth; weapon; welfare; verse; wheat; whisky; whistle; victory; widow; width; will; willingness; vinegar; violence; wire; virtual reality; wisdom; wish; vision; vitamin; witness; volcano; wolf; volunteer; worm; wound; voyage; wrist; x-ray; yacht; zebra;

Nouns belonging to language ability level C1 (328 nouns):

abortion; acceptance; adaptation; administration; aggression; aid; allegation; allowance; amateur; amendment; angle; annoyance; appetite; applause; archaeologist; archaeology; asset; assumption; assurance; auction; audition; awareness; bacteria; beak; blindness; boundary; brass; bribe; bronze; campaign; carriage; cholesterol; clutch; coal; collaboration; commodity; competence; complex; component; consent; constitution; consumption; contestant; controversy; convention; corruption; coverage; cultivation; daycare; dedication; deficiency; delegate; density; deodorant; deputy; destiny; diesel; digestion; discomfort; discrimination; disorder; disrespect; disruption; dissertation; distraction; distress; draught; drawback; dump; duration; ecology; effectiveness; elegance; elite; emission; emperor; empire; enterprise; environmentalist; equation; erosion; establishment; evaluation; exaggeration; exhaust; exhibit; expenses; exploration; exposure; extinction; fabric; fairness; feast; fibre; formula; friction; fright; fund; funding; gadget; gain; garment; gene; generalization; genius; geology; gerund; gesture; globalization; greed; habitat; harassment; hate; hatred; hazard; heading; health care; historian; hospitality; housing; humanity; hygiene; iceberg; idol; illustration; import; indication; industrialization; infrastructure; initiative; injustice; innocence; innovation; insight; inspection; installation; integration; interaction; isolation; itinerary; jargon; jealousy; joint; journal; junk; knob; labour; landmark; launch; lawn; leadership; liability; limitation; literacy; log; logic; loneliness; lounge; machinery; magistrate; mammal; mansion; mat; mechanism; miner; mining; mode; move; nap; necessity; neglect; negotiation; nervousness; networking; newsletter; nickname; nomination; nutrition; obesity; obstacle; occurrence; odds; optimist; organ; overdraft; ownership; ozone; panel; paradise; pastry; peasant; pensioner; perfection; personell; phenomenon; pony; praise; predator; pregnancy; premises; preservation; principle; privilege; probability; productivity; programmer; progression; proposition; prosperity; prostitute; protein; protractor; pulse; purity; pyramid; radiation; rank; rating; ratio; rebellion; recruitment; rectangle; redevelopment; register; reign; relevance; renovation; reproduction; reptile; republic; restriction; retail; revenue; richness; riot; rival; role model; rudeness; runaway; sack; sacrifice; saint; saving; scholar; scholarship; sector; self; self-esteem; selfishness; sequence; serial; setback; sewing; shame; shuttle; shyness; side effect; simplicity; simulation; slang; slavery; slogan; slot; smog; socialist; solicitor; solidarity; solitude; spam; specification; spectrum; speculation; sphere; spokesman; spokesperson; sponsorship; staircase; stamina; stand; statistic; status; status symbol; stereotype; stock market; stocking; straw; stretch; strip; subsidy; subtitles; successor; summit; superior; supervision; supervisor; surgeon; takeover; tank; teamwork; technician; techno; telly; therapist; tobacco; torture; trainee;

transportation; trek; tuition; turnover; uncertainty; unity; usage; walker; warrior; vegetation; veil; vein; well-being; vest; win; vine; wit; witch; workforce; workplace; workshop; youngster;

Nouns belonging to language ability level C2 (360 nouns):

acre; adolescent; advocate; alcoholic; alliance; ambiguity; analogy; anchor; antibiotic; arch; army; artificial intelligence; aspiration; assault; assembly; astronomy; attribute; awe; bark; barn; bet; bias; blackmail; blend; blister; bribery; bureaucracy; burial; capitalism; cargo; casserole; casualty; catastrophe; chancellor; chapel; charisma; cheerfulness; chill; circulation; civilian; clash; cliché; coastline; coldness; combat; comeback; commander; complexion; complexity; conception; confrontation; conscience; consensus; contempt; contraception; contraceptive; contradiction; conversion; conviction; cookie; coral; core; corpse; coup; crack; crackdown; credibility; crystal; cutlery; deception; delegation; denial; deprivation; descendant; desperation; diagnosis; dialect; dice; dignity; diplomacy; discretion; disgust; disposable income; disposition; dispute; dna; dominance; donor; doom; doorway; drought; echo; embrace; empathy; endurance; entity; essence; exile; expenditure; explosive; fake; famine; fireplace; fist; flesh; fluid; follower; forgery; forgiveness; fragrance; fraud; frenzy; frontier; frown; gamble; glue; goodness; grain; grasp; grin; hail; heir; heritage; hesitation; hierarchy; homelessness; horizon; hostage; hostility; humility; hypocrisy; hypothesis; ignorance; illusion; imitation; immune system; impatience; implementation; impossibility; imprisonment; incentive; inclination; individuality; infancy; infant; inheritance; insecurity; insomnia; instinct; instruction; integrity; intellect; intellectual; intensity; intent; interpretation; intervention; intruder; intrusion; irony; irritation; kidney; knot; knuckle; legislation; likelihood; linen; loathing; local; loft; longevity; massacre; masterpiece; materialism; materialist; medication; melody; memorial; mercy; merger; metaphor; millennium; missile; momentum; monopoly; morale; mortality; motion; narrative; narrator; negligence; nerve; nest; nostalgia; nostril; novelty; observer; official; offspring; omission; openness; optimism; ordeal; ornament; orphan; outbreak; output; pact; paradigm; paradox; parallel; particle; pastime; patch; peer pressure; perception; persistence; persuasion; plea; pole; precedent; presumption; prey; proceedings; procession; produce; propaganda; prosecution; prosecutor; protagonist; proverb; province; proximity; psychiatrist; quest; quotation; quote; racist; raid; rash; realm; reasoning; recognition; recollection; recruit; referendum; reform; refuge; regime; relish; remorse; representation; resemblance; resentment; residence; resignation; resilience; resistance; resolution; restraint; retailer; retreat; revelation; reversal; rhyme; ribbon; riches; ritual; rivalry; round; ruling; saddle; sail; saying; scarcity; scenario; schooling; scrap; self-assurance; self-awareness; self-control; self-discipline; self-respect; sensibility; sentiment; shield; sibling; simplification; sin; sincerity; siren; skull; slap; slaughter; snob; socialism; sorrow; spade; spark; spite; spouse; squad; stable; starvation; stimulus; strand; strap; stupidity; sufferer; superiority; suspense; sustainability; syllabus; synonym; talks; taxpayer; tenderness; thinker; threshold; throne; timber; toddler; toughness; tractor; trait; tranquility; trash; treat; treaty; tribute; trilogy; troops; undertaking; unrest; vaccination; vaccine; validity; vandalism; vanity; warehouse; weed; velvet; verdict; veteran; whim; vice; wilderness; villager; willpower; virgin; virtue; vitality; withdrawal; vocation; woodland; workaholic; worship; vow; wrinkle; xenophobia;

Appendix AE

As discussed in Subchapter 12.2, this listing shows in respect to Oxford Wordlist for each vocabulary of school levels ranging from Preparatory to Year 4 unique nouns in unique Wikipedia hyperlinks connecting unique nouns in vocabulary so that nouns are listed separately for each school level (please note that nouns were extracted from Oxford Wordlist based on co-occurrence among nouns of C2 vocabulary of English Vocabulary Profile). For each observed vocabulary ranging from Preparatory to Year 4 a full listing of unique Wikipedia hyperlinks connecting unique nouns in vocabulary can be extracted from listing shown in Appendix AC by taking into consideration only those hyperlinks whose start concept and end concept belong to nouns of currently observed vocabulary among vocabularies ranging from Preparatory to Year 4.

In contrast with Appendix AD, please note that concepts of consecutive ranges of language ability levels of English Vocabulary profile can be considered cumulative so that next ranges of language ability levels almost always (with very few exceptions) contain all concepts belonging to all previous ranges of language ability levels whereas consecutive vocabularies of Oxford Wordlist can be considered only partially cumulative since there is only partial overlap between consecutive vocabularies. These two different kinds of behavior affect also interpretation of Wikipedia hyperlinks connecting unique nouns in respect to both Oxford Wordlist and English Vocabulary Profile so that these hyperlinks can be considered cumulative for English Vocabulary Profile whereas hyperlinks can be considered only partially cumulative for Oxford Wordlist since there is only partial overlap.

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Preparatory (i.e. vocabulary of school level Preparatory)

Alltogether 505 nouns with the following subdivision.

Nouns belonging to school level Preparatory (505 nouns):

accident; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bride; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; cereal; chair; champion; chart; cheese; cherry; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; crowd; cup; cushion; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dust; dvd; eagle; ear; earth; electricity; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; festival; finger; fire; fish; fishing; flame; floor; flower; flute; fly; food; foot; football; fox; fox; friday; friend; frog; fruit; game; garden; gardening; gas; gear; ghost; giraffe; girl; glove; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; headache; heart; heaven; helicopter; helmet; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; ink; island; jacket; jail; jam; jazz; jeans; juice; june; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lighter; lightning; line; lion; lounge; love; lunch; machine; magazine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; orchestra; paint; pair; palace; pancake; paper; parade; parent; park; partner; party; pasta; patch; peace; pear; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pineapple; pink; pirate; pizza; plan; planet; plant; playground; poison; pole; police; pond; pony; present; prince; princess; prize; professor; project; pub; puppy; purple; rabbit; radio; rain; rainbow; rectangle; red; reptile; rescue; restaurant; rice; river; road; robot; rocket; roof; room; ruler; run; runner; running; sack; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; ship; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skateboarding; skating; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; temple; tennis; tent; theatre; thought; thumb; thunder; thursday; tiger; timber; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; triangle; trip; trophy; truck; tuesday; turn; turning; tv; type; umbrella; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; vest; west; whale; wheel; whistle; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (370 nouns):

aeroplane; afternoon; ambulance; animal; apple; arm; army; art; baby; bacon; bag; ball; ballet; balloon; barbecue; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; black; blood; blue; boat; book; bottle; box; boy; bread; breakfast; brother; brush; bus; butterfly; cake; camping; can; candle; car; cash; castle; cat; cave; cereal; chair; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clown; club; cold; colour; competition; computer; concert; cookie; court; cousin; crash; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; devil; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; earth; elephant; engine; face; factory; family; farm; farmer; fat; favourite; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; hand; hat; head; headache; heart; heaven; helicopter; hero; hill; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; june; jungle; kangaroo; kick; kid; king; kitten; lake; land; leg; lemon; leopard; lettuce; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; miss; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mum; music; musical; name; neck; night; noise; number; ocean; paint; pair; palace; paper; parent; park; party; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pirate; pizza; plan; planet; playground; poison; pole; police; pond; pony; present; prince; princess; prize; pub; puppy; purple; rabbit; rain; rainbow; red; rescue; restaurant; river; road; robot; rocket; roof; room; run; runner; running; sack; safety; salad; sand; sandwich; saturday; sauce; school; science; sea; second; set; shark; shed; sheep; ship; shop; shopping; show; shower; side; singing; sink; siren; skateboard; skeleton; ski; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spider; sport; stairs; star; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; temple; tennis; tent; theatre; thought; thumb; thunder; thursday; tiger; timber; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; tractor; traffic; trail; train; training; travel; treasure; tree; trophy; truck; tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; village; wind; window; winner; winter; witch; wolf; woman; wood; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (415 nouns):

aeroplane; afternoon; air; airport; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; basketball; bat; battle; beach; bear; bed; bird; birthday; biscuit; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; bread; breakfast; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; chair; chess; chicken; chocolate; city; class; classroom; climbing; cloud; clown; club; cold; colour; competition; computer; cookie; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; eagle; earth; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; fire; fish; fishing; flame; floor; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gardening; gear; ghost; giraffe; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; headache; heart; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; jam; juice; jungle; kangaroo; kick; kid; king; kitten; lake; land; leg; lemon; leopard; lesson; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; match; meal; meat; medal; medicine; metal; milk; mind; miss; monday; monkey; monster; morning; mother; mouse; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; paint; pair; palace; pancake; paper; parade; parent; park; partner; party; pasta; patch; peace; pencil; penguin; people; person; pet; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince;

lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; miss; monday; money; monkey; monster; morning; mother; motor; mouse; moust; movie; mrs; mud; mum; mushroom; music; musical; name; neck; need; night; noise; november; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; person; pet; piece; pig; pink; pirate; pizza; plan; planet; playground; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rat; red; rescue; rest; restaurant; river; road; robot; rocket; roof; room; rope; round; run; running; salad; sand; sandwich; saturday; school; science; sea; seat; second; september; set; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; shower; side; silver; singing; siren; skeleton; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; stadium; stairs; stand; star; step; storm; story; strawberry; street; summer; sun; sunday; tail; tank; tea; teacher; teaching; team; tent; thought; thursday; tiger; time; toast; today; toilet; tooth; toothbrush; top; towel; town; toy; track; tractor; train; training; tram; treasure; tree; trophy; truck; try; tuesday; tunnel; turkey; turn; turning; tv; uncle; walk; walking; wall; war; waste; watch; water; way; wedding; wednesday; week; weekend; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 3 (520 nouns):

adult; adventure; aeroplane; afternoon; animal; answer; apple; arm; army; arrest; art; baby; bacon; bag; ball; ballet; balloon; bank; barbecue; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; bee; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; brand; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; button; cabin; cake; camel; camping; can; car; carpet; cash; castle; cat; cave; cereal; chain; chair; change; cheese; chess; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; club; coffee; coin; cold; collar; collection; colour; competition; complex; computer; concert; cook; cookie; cooking; cost; cottage; cotton; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dad; dance; dancer; dancing; day; december; desert; desk; dinner; dinosaur; dirt; disco; dive; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; engine; eye; face; fact; factory; fall; family; farm; farmer; fashion; fat; father; favourite; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; gift; girl; glass; glasses; goal; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; hall; hammer; hand; hat; head; heart; heaven; helicopter; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; january; jar; joke; joy; june; jungle; kangaroo; kick; kid; king; kiss; kit; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; lip; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mother; mountain; mouse; mouth; mrs; mud; mum; murder; music; name; neck; need; nest; night; noise; note; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; pub; puppy; purple; rabbit; rain; rainbow; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; salad; sand; sandwich; saturday; sauce; school; science; sea; season; seat; second; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; skiing; skull; sky; sleep; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; towel; town; toy; track; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; white; wife; village; window; wing; winter; witch; wolf; woman; wood; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 4 (512 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; art; baby; bacon; bag; ball; ballet; balloon; barn; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; butterfly; button; cabin; cake; camping; can; car; carpet; cash; castle; cat; cave; century; cereal; chain; chair; cheese; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; clown; club; coffee; cold; collar; colour; competition; computer; concert; contest; cook; cookie; cooking; cost; cottage; court; cousin; cow; crash; cream; creature; cricket; crime; cross; cup; cupboard; dad; dance; dancer; dancing; day; desert; designer; devil; diamond; dinner; dinosaur; dirt; disco; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; emergency; engine; eye; face; fact; factory; fall; family; farm; fashion; fat; father; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; girl; glass; glasses; goal; goat; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; haircut; hall; hammer; hand; hat; head; heart; heaven; helicopter; help; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; jar; joy; june; jungle; kangaroo; kick; kid; killer; king; kiss; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; leaf; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; matter; meal; meat; medal; medicine; mess; message; metal; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mosquito; mother; motor; mountain; mouse; mouth; mrs; mud; mum; murder; murderer; music; musical; name; nature; neck; need; nest; night; noise; note; number; ocean; opening; oven; paint; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; performance; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; poison; pole; police; pony; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rainforest; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; sail; salad; sand; sandwich; saturday; sauce; school; science; sea; season; seat; second; september; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; suitcase; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; waste; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 2 (i.e. vocabulary of school level Year 2)

Alltogether 749 nouns with the following subdivision.

Nouns belonging to school level Preparatory (415 nouns):

aeroplane; afternoon; air; airport; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; basketball; bat; battle; beach; bear; bed; bedroom; bee; bird; birthday; biscuit; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boy; bread; breakfast; bridge; brother; brown; brush; bus; butterfly; cabbage; cake; camera; camping; can; candle; car; case; cash; castle; cat; cave; chair; chess; chicken; chocolate; city; class; classroom; climbing; cloud; clown; club; cold; colour; competition; computer; cookie; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; cup; dance; dancing; day; december; desert; desk; dresser; devil; diary; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dvd; eagle; earth; elephant; engine; evening; face; factory; fair; family; farm; farmer; fat; favourite; feeling; fence; ferry; fire; fish; fishing; flame; floor; fly; food; foot; football; fox; friday; frog; fruit; fun; fur; game; garden; gardening; gear; ghost; giraffe; girl; goal; golf; grass; green; grey; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; headache; heart; hero; hill; hip; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; island; jacket; jail; jam; juice; jungle; kangaroo; kick; king; kitchen; kite; kitten; ladder; lake; land; leg; lemon; leopard; lesson; level; library; light; lightning; line; lion; lounge; love; lunch; machine; man; market; match; meal; meat; medal; medicine; metal; milk; mind; miss; monday; monkey; monster; morning; mother; mouse; movie; mrs; mud; mug; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; paint; pair; palace; pancake; paper; parade; parent; park; partner; party; pasta; patch; peace; pencil; penguin; people; person; pet; pie; pillow; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince; princess; prize; professor; puppy; purple; rabbit; radio; rain; rainbow; red; rescue; restaurant; rice; river; road; robot; rocket; roof; room; run; running; sack; salad; sand; sandwich; saturday; sausage; school; science; sea; second; secret; set; shark; shed; sheep; shoe; shop; shopping; shower; side; singing; siren; ski; skeleton; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; stage; stairs; star; storey; storm; story; street; summer; sun; sunday; tail; tea; teacher; team; tent; thought; thursday; tiger; timber; time; today; toe; toilet; tooth; top; torch; town; toy; tractor; train; training; treasure; tree; triangle; trophy; truck; tuesday; turn; turning; tv; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; video; village; wind; window; winter; witch; volcano; wolf; woman; wood; world; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (460 nouns):

adult; aeroplane; afternoon; ambulance; animal; apple; arm; army; art; baby; bacon; bag; ball; balloon; barbecue; barn; basketball; bat; battle; beach; bear; bed; bedroom; bee; bird; birthday; biscuit; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boy; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cake; camel; camping; can; candle; car; carpet; cash; castle; cat; cave; chain; chair; chess; chest; chicken; chip; chocolate; circle; city; class; classroom; climbing; clothes; clown; club; coffee; cold; colour; competition; computer; contest; cook; cookie; cooking; coral; cost; cottage; count; court; cousin; cow; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dance; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; disco; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; dvd; earth; elephant; engine; eye; face; factory; fall; family; farm; farmer; fat; favourite; field; fire; fish; fishing; flash; floor; fly; fog; food; foot; football; forest; fox; frame; friday; friend; frog; fruit; fun; fur; game; garden; gate; gear; gentleman; ghost; gift; giraffe; girl; glass; glasses; goal; gold; golf; grass; green; grey; ground; group; guitar; gun; gymnastics; hair; haircut; hand; hat; head; headache; heart; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; instructor; island; jacket; jail; joke; joy; jungle; kangaroo; kick; king; kiss; kitten; knife; lady; lake; land; lawn; leaf; leg; lemon; leopard; library; life; light; lightning; line; lion; living; lounge; love; lunch; lunchtime; machine; man; march; market; mask; master; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; miss; monday; money; monkey; monster; morning; mother; motor; mouse; mouth; mrs; mud; mum; mushroom; music; musical; name; neck; need; night; noise; november; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; person; pet; piece; pig; pink; pirate; pizza; plan; planet; playground; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rat; red; rescue; rest; restaurant; river; road; robot; rocket; roof; room; rope; round; run; running; salad; sand; sandwich; saturday; school; science; sea; seat; second; september; set; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; shower; side; silver; singing; siren; skeleton; sky; sleep; snake; snow; son; song; sound; soup; space; speed; spelling; spider; stage; stairs; star; storey; storm; story; street; summer; sun; sunday; tail; tea; teacher; team; tent; thought; thursday; tiger; timber; time; today; toe; toilet; tooth; top; torch; town; toy; tractor; train; training; treasure; tree; triangle; trophy; truck; try; tuesday; tunnel; turkey; turn; turning; tv; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding; wednesday; week; weekend; west; whale; wheel; whistle; white; wife; village; window; wing; winter; witch; wolf; woman; wood; wool; word; world; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (749 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; argument; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; barbecue; bark; barn; basketball; bat; bathroom; battle; bay; beach; beak; bear; beard; bed; bedroom; bee; beer; bench; bird; birthday; biscuit; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boot; border; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; bug; building;

bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; calf; camel; camera; camp; camping; can; cancer; candle; car; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; cemetery; chain; chair; challenge; chat; chef; chess; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; cleaner; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; college; colour; community; competition; computer; container; contest; continent; cook; cookie; cooking; cooperation; coral; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; culture; cup; cupboard; curriculum; customer; cutlery; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dice; diesel; dimension; dinner; dinosaur; direction; directions; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; drought; duck; dud; eagle; earth; elephant; enemy; engine; episode; evening; event; evil; exercise; eye; face; factory; fair; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fireplace; fish; fishing; flame; flash; flight; flood; floor; flour; fluid; fly; food; foot; football; force; forest; form; fox; frame; freezer; friday; friend; frog; frost; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gate; gear; gentleman; ghost; gift; giraffe; girl; girlfriend; glass; glasses; glue; goal; god; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; hat; hate; head; headache; heart; heat; hero; hill; hip; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; insect; instructor; interaction; island; jacket; jail; jam; jewellery; joke; joy; judge; jug; juice; jungle; junk; kangaroo; kite; killing; kilometre; king; kiss; kitchen; kite; kitten; knife; lab; laboratory; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leaf; leaf; leg; legend; lemon; lemonade; length; leopard; lesson; level; library; lie; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; machinery; magic; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; mechanic; medal; medicine; member; menu; mercy; mess; message; metal; metre; microphone; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; motor; mouse; mouth; movie; mrs; mud; mug; mum; museum; mushroom; music; musical; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; november; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parade; paragraph; parcel; parent; park; partner; party; pasta; patch; paw; peace; pen; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; roundabout; rubber; run; running; sack; salad; sand; sandwich; saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; september; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; solution; son; song; sound; soup; south; space; speed; spelling; spider; spinach; spirit; spoon; spy; square; stable; stadium; stage; staircase; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; sunday; survival; sweets; symbol; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; temper; tent; thermometer; thought; thunderstorm; thursday; tiger; timber; time; tin; toast; today; toe; toilet; tongue; tooth; toothbrush; top; torch; touch; towel; tower; town; toy; track; tractor; train; training; treasure; tree; trophy; trouble; truck; truth; try; tuesday; tunnel; turkey; turn; turning; tv; uncle; uniform; unit; university; walk; walking; wall; valley; war; wardrobe; warrior; waste; watch; water; waterfall; wave; way; website; wedding; wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yacht; yard; year; yellow; zebra; zone; zoo;

Nouns belonging to school level Year 3 (642 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; animal; ant; apple; arm; army; art; august; baby; back; bacon; bag; ball; balloon; banana; barbecue; bark; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; bee; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boyfriend; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; camel; camera; camp; camping; can; cancer; car; carnival; carpet; carrot; cartoon; case; cash; cast; castle; cat; cave; chain; chair; challenge; chat; chef; chess; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; club; code; coffee; cold; college; colour; competition; computer; cook; cookie; cooking; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; cup; cupboard; customer; cutlery; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dice; dinner; dinosaur; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fish; fishing; flash; flight; floor; flour; fly; food; foot; football; force; forest; form; fox; frame; friday; friend; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gate; gear; ghost; gift; girl; giraffe; giraffe; glass; glasses; glue; goal; god; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; heart; heat; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; island; jacket; jail; jam; jewellery; joke; joy; judge; jug; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; lab; laboratory; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leg; legend; lemon; lemonade; leopard; lesson; level; library; lie; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; magic; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; medal; medicine; member; menu; mercy; mess; message; metal; metre; microphone; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; mouse; mouth; mrs; mud; mug; mum; museum; music; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; sack; salad; sand; sandwich; saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spirit; spoon; square; stadium; stage; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; sunday; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; tent; thought; thunderstorm; thursday; tiger; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; train; training; treasure; tree; trophy; trouble; truck; truth; try; tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; walk; walking; wall; valley; war; wardrobe; warrior; waste; watch; water; waterfall; wave; way; website; wedding; wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 4 (612 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; bark; barn; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boot; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; butterfly; cabbage; cake; camera; camp; camping; can; cancer; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; chain; chair; challenge; chat; chef; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; colour; competition; computer; container; contest; cook; cookie; cooking; cost; cottage; cough; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; cross; crystal; cup; cupboard; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dinner; dinosaur; disco; distance; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fair; fall; family; farm; fat; feeling; fence; ferry; field; fire; fish; fishing; flash; flight; floor; flour; fly; food; foot; football; force; forest; form; fox; frame; freezer; friday; friend; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gate; gear; ghost; girl; girlfriend; glass; glasses; glue; goal; god; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; hat; hate; head; heart; heat; hero; hill; hip; history; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; island; jacket; jail; jam; jewellery; joy; judge; jug; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; laser; lawn; lead; leader; leaf; leaf; leg; legend; lemon; lemonade; leopard; lesson; level; library; lie; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; lunchtime; machine; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; mechanic; medal; medicine; mess; message; metal; metre; microphone; midnight; milk; mind; mirror; miss; missile; monday; money; monkey; monster; month; morning; mother; motor; mouse; mouth; mrs; mud; mug; mum; museum; music; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; red; rescue; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; sack; salad; sand; sandwich; saturday; sausage; scarf; school; science; sea; seat; second; secret; seed; september; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spinach; spirit; spoon; square; stadium; stage; stairs; stand; star; step; stomach; storey; storm; story; straw; strawberry; street; string; student; summer; sun; sunday; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; tent; thought; thunderstorm; thursday; tiger; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; train; training; treasure; tree; trophy; trouble; truck; truth; try; tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; university; walk; walking; wall; valley; war; wardrobe; warrior; waste; watch; water; waterfall; wave; way; website; wedding; wednesday; weed; week; weekend; veil; west; whale; wheel; whistle; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; wrist; writing; yard; year; yellow; zebra; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 3 (i.e. vocabulary of school level Year 3)

Alltogether 1051 nouns with the following subdivision.

Nouns belonging to school level Preparatory (459 nouns):

aeroplane; afternoon; air; airport; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; bag; ball; ballet; balloon; banana; barbecue; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bride; bridge; brother; brush; bus; butterfly; cabbage; cake; camera; camping; can; car; case; cash; castle; cat; cave; cereale; chair; champion; cheese; chess; chicken; child; chocolate; circus; city; class; classroom; climbing; clinic; cloud; club; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crab; crash; crew; cricket; crocodile; cross; crowd; cup; dance; dancing; day; december; desert; desk; dessert; devil; diary; dinner; dinosaur; disco; diving; dog; doll; dolphin; door; drawing; dream; dress; drink; drive; duck; dust; ear; earth; electricity; elephant; engine; evening; face; factory; family; farm; farmer; fat; favourite; feeling; fence; ferry; finger; fire; fish; fishing; floor; flower; fly; food; foot; football; fox; friday; friend; frog; fruit; game; garden; gas; gear; ghost; girl; goal; gold; golf; grass; green; grey; guitar; gun; gymnastics; hair; hall; ham; hand; hat; hate; head; heart; heaven; helicopter; helmet; hero; hill; history; hockey; holiday; home; homework; honey; hope; horse; hospital; hotel; house; hunting; idea; ink; island; jacket; jail; jam; jeans; juice; jungle; kangaroo; kick; kid; king; kitchen; kite; kitten; ladder; lake; land; language; leg; lemon; leopard; lesson; lettuce; level; library; light; lightning; line; lion; lounge; love; lunch; machine; magazine; man; market; mat; match; meal; meat; medal; medicine; metal; milk; mind; miss; model; monday; monkey; monster; morning; mother; mouse; mrs; mud; mug; mum; museum; music; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; pancake; paper; parent; park; partner; party; patch; peace; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pineapple; pink; pirate; pizza; plan; planet; plant; playground; pole; police; pond; pony; present; prince; princess; prize; professor; pub; puppy; rabbit; radio; rain; rainbow; rectangle; red; rescue; restaurant; rice; river; road; robot; rocket; room; ruler; run; running; safety; salad; sand; sandwich; saturday; sauce; sausage; school; science; sea; second; secret; set; shark; shed; sheep; ship; shirt; shoe; shop; shopping; show; shower; side; singing; sink; siren; size; skate; skateboard; skeleton; skiing; sky; sleep; snake; snow; song; sound; soup; space; speed; spelling; spider; sport; stage; stairs; star; storey; storm; story; street; sugar; summer; sun; sunday; sweet; sword; system; tail; tea; teacher; team; television; tennis; tent; theatre; thought; thunder; thursday; tiger; time; today; toe; toilet; tomato; tooth; top; torch; town; toy; traffic; trail; train; training; travel; treasure; tree; trip; trophy; truck; tuesday; turn; turning; tv; type; uncle; walk; walking; wall; war; watch; water; waterfall; wave; way; wedding;

wednesday; week; weekend; vest; whale; wheel; white; video; village; wind; window; winner; winter; witch; volcano; wolf; woman; wood; world; worm; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 1 (520 nouns):

adult; adventure; aeroplane; afternoon; animal; answer; apple; arm; army; arrest; art; baby; bacon; bag; ball; ballet; balloon; bank; barbecue; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; bee; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bottle; box; boxing; boy; brand; bread; breakfast; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; button; cabin; cake; camel; camping; can; car; carpet; cash; castle; cat; cave; cereal; chain; chair; change; cheese; chess; chest; chicken; chick; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clock; clothes; club; coffee; coin; cold; collar; collection; colour; competition; complex; computer; concert; cook; cookie; cooking; cost; cottage; cotton; count; cousin; cow; crab; craft; crash; cream; creature; cricket; crime; crocodile; cross; cup; cupboard; dad; dance; dancer; dancing; day; december; desert; desk; devil; diamond; dinner; dinosaur; dirt; disco; dive; diving; dog; doll; dolphin; donkey; door; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; engine; eye; face; fact; factory; fall; family; farm; farmer; fashion; fat; father; favourite; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; friend; frog; fruit; fun; fur; game; garden; gate; gear; ghost; gift; girl; glass; glasses; goal; god; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; hall; hammer; hand; hat; head; heart; heaven; helicopter; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; january; jar; joke; joy; june; jungle; kangaroo; kick; kid; king; kiss; kit; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; lip; living; lounge; love; lunch; luncheon; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; microphone; midnight; milk; minute; miss; monday; money; monkey; monster; morning; mother; mountain; mouse; mouth; Mrs; mud; mum; murder; music; name; neck; need; nest; night; noise; note; number; ocean; opening; oven; owl; paint; painting; pair; palace; paper; parent; park; party; pastry; patch; pencil; penguin; people; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; pole; police; pond; pony; port; potato; prawn; present; prince; princess; prize; problem; pub; puppy; purple; rabbit; rain; rainbow; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; salad; salad; sand; sandwich; saucer; sauce; scarf; school; science; sea; season; seat; second; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shot; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; summer; sun; sunday; sweat; sword; tail; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; thursday; tiger; time; toast; today; toilet; tomato; tooth; towel; town; toy; track; train; training; travel; treasure; tree; trophy; truck; try; tuesday; tunnel; turn; turning; tv; type; uncle; walk; walking; wall; van; war; warehouse; watch; water; way; wedding; wednesday; week; weekend; vegetable; whale; wheel; white; wife; village; window; wing; winter; witch; wolf; woman; wood; word; world; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 2 (642 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; animal; ant; apple; arm; army; art; august; baby; back; bacon; bag; ball; balloon; banana; barbecue; bark; basketball; bat; bathroom; battle; bay; beach; bed; bedroom; bee; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boy; boyfriend; brain; bread; breakfast; breath; breed; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; business; butter; butterfly; cabbage; cake; calculator; camel; camera; camp; camping; can; cancer; car; carnival; carpet; carrot; cartoon; case; cash; castle; cat; cave; chain; chair; challenge; chat; chef; chess; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; club; code; coffee; cold; college; colour; competition; computer; cook; cookie; cooking; cost; cottage; cough; count; counter; country; court; cousin; cow; crab; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crystal; cup; cupboard; customer; cutlery; dance; dancing; daughter; day; death; december; deck; deer; desert; desk; dessert; devil; diamond; diary; dice; dinner; dinosaur; disco; disease; distance; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fall; family; fantasy; farm; farmer; fat; favourite; feeling; fence; ferry; field; fire; fish; fishing; flash; floor; flower; fly; food; foot; football; force; forest; form; fox; frame; friday; friend; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gate; gear; ghost; gift; girl; glass; glasses; glue; goal; god; gold; golf; grass; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; ham; hand; hat; hate; head; heart; heat; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; inch; island; jacket; jail; jam; jewellery; joke; joy; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; lab; laboratory; ladder; lady; lake; lamb; land; laser; lead; leader; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; liar; library; lie; life; light; lightning; line; lion; living; log; lounge; love; lunch; luncheon; machine; magic; mail; man; mango; march; mark; market; mask; master; match; matter; may; meal; meat; medal; medicine; member; menu; mess; message; metal; microphone; midnight; milk; mind; mirror; miss; missile; monster; month; morning; mother; mouse; mouth; Mrs; mud; mug; mum; murder; muscle; museum; music; mystery; name; nap; neck; necklace; need; nest; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; opera; oven; owl; pain; paint; painting; pair; palace; pan; pancake; paper; parcel; parent; park; partner; party; patch; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pond; pony; pork; port; potato; prawn; present; president; prince; princess; prize; problem; professor; promise; puppy; purple; push; rabbit; radio; rain; rainbow; rat; razor; red; rescue; research; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; rule; run; running; runway; saddle; safety; sailing; salad; salt; sand; sandwich; Saturday; sausage; scarf; school; science; scratch; sea; seat; second; secret; seed; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shorts; shot; shoulder; shower; side; sign; silver; singing; sir; siren; skate; skeleton; skin; skirt; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spirit; spoon; square; stadium; stage; stairs; stand; star; step; stomach; storey; store; strong; student; summer; sun; sunday; tail; talk; tank; tea; teacher; teaching; team; teaspoon; teenager; tent; thought; thunderstorm; thursday; tiger; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; train; training; treasure; tree; trophy; trouble; truck; truth; try; tuesday; tunnel; turn; turning; tv; uncle; uniform; unit; walk; walking; wall; valley; van; wardrobe; warrior; watch; water; waterfall; wave; way; website; wedding; wednesday; week; weekend; veil; whale; wheel; white; video; wife; village; wind; window; wing; winter; witch; volcano; wolf; woman; wood; word; world; worry; wrist; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 3 (1051 nouns):

account; accuracy; ache; act; action; actor; ad; addition; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; album; alcohol; allowance; alphabet; angel; angle; animal; ankle; answer; ant; apartment; apple; area; arm; army; arrest; art; artist; attention; audience; august; aunt; autumn; award; baby; back; backpack; bacon; bag; bakery; balcony; ball; ballet; balloon; banana; bandage; bank; barbecue; barber; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bean; bear; beauty; bed; bedroom; bee; beef; beer; behaviour; bench; berry; bicycle; bike; bin; bird; birthday; bit; bite; black; blackboard; blade; blanket; blood; blue; boat; body; bomb; bone; book; booking; bottle; bowl; box; boxing; boy; boyfriend; brain; brake; branch; brand; bread; breakfast; breath; breed; brick; bride; bridge; brother; brown; brush; bucket; building; bull; bullet; bunch; bus; business; butter; butterfly; button; cabbage; cabin; cake; calculator; calendar; camel; camera; camp; camping; campsite; can; cancer; cap; car; carnival; carpet; carrot; cartoon; case; cash; casserole; cast; castle; cat; cause; cave; ceiling; cereal; chain; chair; challenge; champion; chance; change; chat; check; cheese; chef; chess; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; clutch; coal; coat; coconut; code; coffee; coin; cola; cold; collar; collection; college; colour; column; comedy; comic; company; competition; complex; computer; concert; cook; cookie; cooking; core; corn; cost; costume; cottage; cotton; cough; count; counter; country; courage; court; cousin; cow; crab; crack; craft; crash; cream; creature; crew; cricket; crime; crocodile; cross; crowd; crustal; cup; cupboard; curve; customer; cutlery; dad; dance; dancer; dancing; darkness; daughter; dawn; day; death; december; deck; deer; desert; desire; desk; dessert; detective; devil; diamond; diary; dice; dinner; dinosaur; dirt; disaster; disc; disco; disease; disguise; dishwasher; disk; distance; dive; diver; diving; dog; doll; dolphin; donkey; door; drawer; drawing; dream; dress; drink; drive; drop; drum; dust; duty; ear; earth; earthquake; east; edge; electricity; element; email; empire; enemy; energy; engine; enthusiasm; entrance; envelope; error; evening; evil; excitement; exercise; experiment; expert; explosion; explosive; eye; face; fact; factory; fall; family; fantasy; farm; farmer; fashion; fat; father; favourite; fear; feeling; female; fence; ferry; field; figure; finger; fish; fish; fishing; fist; flash; flat; flesh; flight; floor; flower; fly; fog; food; foot; football; force; forest; form; fortune; fox; frame; friday; friend; fright; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gas; gate; gear; ghost; gift; girl; glass; glasses; glue; goal; goalkeeper; god; gold; golf; government; grandmother; grandson; grass; green; grey; grin; groom; ground; group; guard; guide; guitar; gun; gym; gymnastics; hail; hair; hairdresser; hall; ham; hammer; hand; happiness; harmony; hat; hate; head; health; heat; heaven; hedge; height; helicopter; hell; helmet; hero; hill; history; hobby; hockey; hole; holiday; home; homework; honesty; honey; hope; horn; horse; hospital; hotel; hour; house; hope; hug; human; hunting; husband; ice; idea; imagination; ink; information; ink; invasion; invention; investigation; iron; island; jacket; jail; jam; january; jar; jaw; jeans; jewellery; joke; journal; journey; joy; juice; july; june; jungle; kangaroo; keeper; kettle; kick; kid; killing; king; kiss; kit; kitchen; kite; kitten; knife; knot; lab; laboratory; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; launch; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; liar; library; lie; life; light; lightning; line; link; lion; lip; literacy; litre; liver; living; log; lounge; love; luck; luggage; lunch; luncheon; machine; magazine; magic; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; mayor; meal; meat; medal; medication; medicine; meeting; member; membership; menu; mess; message; metal; microphone; midnight; milk; mind; miner; minute; mirror; miss; missile; mist; mix; mixture; mode; model; monday; money; monkey; monster; month; moonlight; morning; mother; mountain; mouse; mouth; Mr; Mrs; mud; mug; mum; murder; muscle; museum; music; mystery; name; nap; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; notice; number; nurse; oak; object; obstacle; ocean; october; officer; oil; onion; opening; opera; oven; owl; owner; oxygen; pace; pack; pain; paint; painting; pair; palace; pan; pancake; paper; parachute; parcel; parent; park; parking; partner; party; password; pastry; patch; pattern; pea; peace; peach; pencil; penguin; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pineapple; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; pocket; poem; point; pole; police; pond; pony; pork; port; poster; potato; prawn; present; president; priest; prince; princess; prison; prisoner; prize; problem; professional; professor; promise; property; pub; pudding; puppy; purple; push; pyramid; quest; question; quiet; quiz; rabbit; radio; rain; rainbow; raincoat; rat; razor; reason; recipe; rectangle; red; reflection; region; relief; reply; report; rescue; research; rest; restaurant; revenge; rice; right; river; road; robbery; robot; rock; rocket; roof; room; rope; rose; round; rubber; rule; ruler; run; running; runway; saddle; safety; sailing; salmon; salt; sand; sandwich; Saturday; saucer; sausage; scar; scarf; school; science; scientist; scrap; scratch; sea; season; seat; second; secret; security; seed; self; sense; series; set; setting; shadow; shape; shark; shed; sheep; sheet; shield; ship; shirt; shoe; shooting; shop; shopping; shorts; shot; shoulder; show; shower; side; sign; silence; silver; singer; singing; sink; sir; siren; sister; site; size; skate; skateboard; skeleton; skiing; skill; skin; skirt; sky; slap; sleep; smile; smoke; smoking; snack; snake; snow; soap; soil; soldier; son; song; sound; soup; source; south; space; species; speech; speed; spelling; sphere; spider; spirit; spoon; sport; squid; square; stadium; stage; stairs; stand; star; state; statue; steak; steam; step; stick; stomach; stone; storey; storm; story; straw; strawberry; stream; street; stretch; strike; string; student; studio; study; substance; sugar; summer; sun; sunday; sunglasses; sunlight; supermarket; supporter; surface; surfing; surroundings; swan; sweat; sweet; switch; sword; system; tail; talk; tank; taste; tea; teacher; teaching; team; teaspoon; teenager; telescope; television; tennis; tent; test; text; theatre; thought; thunder; thunderstorm; thursday; tick; tiger; time; tin; title; toast; today; toe; toilet; tomato; tomb; tongue; tooth; top; torch; tomorrow; touch; tournament; towel; tower; town; toy; track; traffic; trail; train; training; transport; travel; tray; treasure; tree; tribe; trip; troops; trophy; trouble; truck; trumpet; truth; try; tube; tuesday; tunnel; turn; turning; tv; twin; type; uncle; underwear; uniform; unit; walk; walking; wall; waste; valley; van; war; wardrobe; warehouse; warrior; watch; water; waterfall; wave; way; weapon; weather; website; wedding; wednesday; week; weekend; vegetable; weight; veil; vest; whale; wheel; white; vice; video; wife; village; wind; window; windscreen; vine; wine; wing; winner; winter; violin; wire; witch; volcano; wolf; woman; wood; word; world; worm; worry; vote; wrist; writer; writing; yard; year; yellow; zebra; zoo;

Nouns belonging to school level Year 4 (825 nouns):

act; action; actor; ad; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; angel; animal; ankle; answer; ant; apartment; apple; area; arm; army; art; attention; august; aunt; award; baby; back; backpack; bacon; bag; balcony; ball; ballet; balloon; banana; bandage; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; beauty; bed; bedroom; beef; beer; behaviour; bench; bicycle; bike; bin; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boxing; boy; boyfriend; brain; branch; bread; breakfast; breath; breed; brick; bridge; brother; brown; brush; bucket; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; ceiling; cereal; chain; chair; challenge; champion; championship; chance;

chat; cheese; chef; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; coat; code; coffee; cold; collar; colour; comedy; comic; competition; computer; concert; cook; cookie; cooking; cost; costume; cottage; cough; country; courage; court; cousin; cow; crack; craft; cream; creature; crew; cricket; crime; cross; cup; cupboard; dance; dancing; darkness; daughter; day; death; deck; deer; desert; dessert; detective; devil; diamond; diary; dinner; dinosaur; dirt; disaster; disco; disguise; distance; dog; doll; door; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; electricity; element; elephant; enemy; energy; engine; envelope; evening; evil; excitement; exercise; experiment; explosion; eye; face; fact; factory; fall; family; farm; fashion; fat; father; fear; feeling; fence; field; fight; figure; fire; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forest; form; fox; grandmother; grass; green; grey; grin; ground; group; guard; guide; guitar; gun; gym; gymnastics; hail; hair; hall; ham; hammer; hand; happiness; hat; hate; head; health; heart; heat; heaven; height; helicopter; hell; helmet; hero; hill; history; hole; holiday; home; homework; honey; hope; hour; house; hug; human; hunting; husband; ice; idea; imagination; information; invasion; invention; island; jacket; jail; jam; jar; jeans; jewellery; journey; joy; juice; July; June; jungle; junk; kangaroo; kettle; kick; kid; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; library; life; light; lightning; line; lion; lounge; love; lunch; luncheon; machine; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; meal; meat; medal; medicine; meeting; mess; message; metal; midnight; milk; mind; minute; mirror; miss; mist; mix; mixture; model; monday; money; monkey; monster; month; morning; mother; mouse; Mrs; mud; mum; museum; music; mystery; name; nap; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; note; notice; number; object; obstacle; ocean; october; office; oil; onion; opening; oven; owner; pack; pain; paint; pair; palace; paper; parachute; parcel; parent; park; party; patch; pattern; peace; peach; pencil; penguin; people; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; pocket; point; pole; police; pony; post; poster; present; president; prince; princess; prison; price; problem; professional; professor; property; puppy; purple; push; rabbit; radio; rain; rainbow; raincoat; rat; reason; red; rectangle; red; reply; rescue; rest; restaurant; revenge; rice; right; river; road; robbery; robot; rock; rocket; roof; room; rope; rose; round; rubber; ruler; run; running; saddle; safety; salad; sandwich; Saturday; sauce; sausage; scarf; school; science; scientist; sea; season; seat; second; secret; security; seed; self; sense; series; set; setting; shadow; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shorts; shot; shoulder; show; shower; side; sign; silence; silver; singer; singing; sink; sir; siren; size; skate; skateboard; skeleton; skiing; skill; skull; sky; slap; sleep; smile; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; species; speed; spelling; sphere; spider; spoon; sport; squid; square; stadium; stand; stand; star; state; statue; step; stick; stomach; stone; storey; storm; story; strawberry; stream; street; stretch; strike; string; stroke; study; sugar; summer; sun; Sunday; sunlight; supermarket; surface; surfing; surroundings; sweat; sweet; switch; sword; system; tail; talk; tank; taste; tea; teacher; teaching; team; television; temple; tennis; tent; test; thought; thunder; Thursday; tick; tiger; time; tin; toast; today; toe; toilet; tomato; tongue; tooth; top; torch; tornado; touch; tournament; towel; tower; town; toy; track; traffic; trail; train; training; transport; travel; treasure; tree; trip; trophy; trouble; truck; try; tube; Tuesday; tunnel; turn; turning; tv; twin; type; uncle; walk; walking; wall; valley; van; war; wardrobe; warehouse; warrior; watch; water; waterfall; wave; way; weapon; wedding; Wednesday; week; weekend; vegetable; weight; whale; wheel; whistle; white; video; wife; village; wind; window; vine; wing; winner; winter; witch; volcano; wolf; woman; wood; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zoo;

Unique nouns in unique Wikipedia hyperlinks connecting unique nouns for observed vocabulary of Year 4 (i.e. vocabulary of school level Year 4)

Alltogether 1072 nouns with the following subdivision.

Nouns belonging to school level Preparatory (459 nouns):

accident; aeroplane; afternoon; air; airport; ambulance; angel; animal; ant; apple; area; arm; army; art; august; baby; back; bacon; badge; bag; ball; ballet; balloon; banana; bark; basket; basketball; bat; battle; beach; bear; bed; bird; birthday; bit; bite; black; blood; blue; boat; bomb; bone; book; bottle; bowl; box; boy; branch; bread; breakfast; bridge; brother; brush; bus; butterfly; cake; camera; camping; can; car; case; cash; castle; cat; cave; century; cereal; chain; chair; challenge; chat; chef; chest; chicken; child; chin; chip; chocolate; circus; city; class; classroom; climbing; clinic; cloud; clown; club; coast; cold; colour; competition; computer; concert; cookie; costume; country; court; cousin; crash; crew; cricket; crime; cross; crowd; cup; dance; dancing; darkness; daughter; day; death; deck; deer; desert; dessert; devil; diamond; diary; dinner; dinosaur; dirt; disaster; disco; disguise; distance; dog; doll; door; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; electricity; elephant; enemy; evening; evil; excitement; exercise; experiment; explosion; eye; face; fact; factory; fall; family; farm; fat; feeling; fence; field; fire; fish; fishing; floor; flower; fly; fog; food; foot; football; fox; Friday; friend; frog; fruit; game; garden; gardening; gate; gear; ghost; girl; glass; glasses; goal; gold; golf; government; grandmother; grass; green; grey; grin; ground; group; guard; guitar; gun; gym; gymnastics; hail; hair; hall; ham; hammer; hand; happiness; hat; hate; head; health; heart; heat; heaven; height; helicopter; hell; helmet; hero; hill; history; hole; holiday; home; homework; honey; hope; hour; house; hug; human; hunting; husband; ice; idea; imagination; information; invasion; invention; island; jacket; jail; jam; jar; jeans; jewellery; journey; joy; juice; July; June; jungle; junk; kangaroo; kettle; kick; kid; king; kitchen; kite; kitten; ladder; lady; lake; land; landing; lane; language; lap; laptop; laser; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; library; life; light; lightning; line; lion; lounge; love; lunch; luncheon; machine; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; meal; meat; medal; medicine; meeting; mess; message; metal; midnight; milk; mind; minute; mirror; miss; mist; mix; mixture; model; monday; money; monkey; monster; month; morning; mother; mouse; Mrs; mud; mum; museum; music; musical; name; nap; neck; news; newspaper; night; noise; nose; number; ocean; office; paint; pair; palace; paper; parade; parent; park; party; patch; pattern; peace; peach; pencil; penguin; people; person; pet; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; pocket; point; pole; police; pony; post; poster; present; president; prince; princess; prison; price; problem; professional; professor; property; puppy; purple; push; rabbit; radio; rain; rainbow; raincoat; rat; reason; red; rectangle; red; reply; rescue; rest; restaurant; revenge; rice; right; river; road; robbery; robot; rock; rocket; roof; room; rope; rose; round; rubber; ruler; run; running; saddle; safety; salad; sandwich; Saturday; sauce; sausage; scarf; school; science; scientist; sea; season; seat; second; secret; security; seed; self; sense; series; set; setting; shadow; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shorts; shot; shoulder; show; shower; side; sign; silence; silver; singer; singing; sink; sir; siren; size; skate; skateboard; skeleton; skiing; skill; skull; sky; slap; sleep; smile; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; species; speed; spelling; sphere; spider; spoon; sport; squid; square; stadium; stand; stand; star; state; statue; step; stick; stomach; stone; storey; storm; story; strawberry; stream; street; stretch; strike; string; stroke; study; sugar; summer; sun; Sunday; sunlight; supermarket; surface; surfing; surroundings; sweat; sweet; switch; sword; system; tail; talk; tank; taste; tea; teacher; teaching; team; television; temple; tennis; tent; test; thought; thunder; Thursday; tick; tiger; time; tin; toast; today; toe; toilet; tomato; tongue; tooth; top; torch; tornado; touch; tournament; towel; tower; town; toy; track; traffic; trail; train; training; transport; travel; treasure; tree; trip; trophy; trouble; truck; try; tube; Tuesday; tunnel; turn; turning; tv; twin; type; uncle; walk; walking; wall; valley; van; war; wardrobe; warehouse; warrior; watch; water; waterfall; wave; way; weapon; wedding; Wednesday; week; weekend; vegetable; weight; whale; wheel; whistle; white; video; wife; village; wind; window; vine; wing; winner; winter; witch; volcano; wolf; woman; wood; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 1 (512 nouns):

adult; adventure; aeroplane; afternoon; ambulance; animal; answer; apple; arm; army; art; baby; bacon; bad; ball; ballet; balloon; barn; baseball; basket; basketball; bat; battle; beach; bear; bed; bedroom; beef; bird; birthday; bit; black; blanket; blood; blue; boat; body; book; bone; book; boot; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; bread; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; butter; butterfly; button; cabin; cake; camping; can; car; carpet; cash; castle; cat; cave; century; cereal; chain; chair; cheese; chest; chicken; child; chin; chip; chocolate; circle; circus; city; class; classroom; climbing; clothes; clown; club; code; coffee; cold; collar; colour; competition; computer; concert; contest; cook; cookie; cooking; cost; cottage; court; cousin; cow; craft; crash; cream; creature; crew; cricket; crime; cross; cup; cupboard; dance; dancing; daughter; day; death; designer; devil; diamond; dinner; dinosaur; dirt; disco; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; emergency; engine; eye; face; fact; factory; fall; family; farm; fashion; fat; father; field; fire; fish; fishing; flash; floor; flower; fly; fog; food; foot; football; forest; fox; frame; Friday; friend; frog; fruit; fun; fur; game; garden; gardening; gate; gear; ghost; girl; glass; glasses; goal; gold; golf; grandmother; grass; green; grey; ground; group; guitar; gun; gym; gymnastics; hair; haircut; hall; hammer; hand; hat; head; heart; heaven; helicopter; help; hero; hill; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; hunting; idea; information; island; jacket; jail; jar; joy; June; jungle; kangaroo; kettle; kick; kid; killer; king; kitten; knife; lady; lake; land; lane; lap; laptop; lawn; leaf; learning; leg; lemon; leopard; lettuce; library; life; light; lightning; line; lion; living; lounge; love; lunch; luncheon; machine; man; march; market; mask; master; mat; match; matter; meal; meat; medal; medicine; mess; message; metal; midnight; milk; minute; miss; Monday; money; monkey; monster; morning; mosquito; mother; motor; mountain; mouse; mouth; Mrs; mud; mum; murder; murderer; music; musical; name; nature; neck; need; nest; night; noise; note; number; ocean; opening; oven; paint; pair; palace; paper; parent; park; party; patch; pen; pencil; penguin; people; performance; person; pet; picnic; piece; pig; pink; pirate; pizza; plan; planet; playground; pocket; point; poison; pole; police; pony; present; prince; princess; prize; problem; puppy; purple; rabbit; rain; rainbow; rainforest; rat; reason; red; rescue; rest; restaurant; right; river; road; robot; rocket; roof; room; rope; rose; round; run; running; safety; sail; salad; sand; sandwich; Saturday; sauce; scarf; school; science; sea; season; seat; second; September; set; shadow; shape; shark; shed; sheep; sheet; ship; shooting; shop; shopping; shod; show; shower; side; silver; singer; singing; sink; siren; skateboard; skeleton; ski; skiing; skull; sky; sleep; snack; snake; snow; son; song; sound; soup; space; speed; spider; sport; stadium; stairs; stand; star; step; storm; story; strawberry; street; stretch; strike; sugar; suitcase; summer; sun; Sunday; sweat; sweet; tail; talk; tank; taste; tea; teacher; teaching; team; tennis; tent; thought; thunder; Thursday; tiger; time; toast; today; toilet; tomato; tongue; tooth; top; towel; town; toy; track; tractor; train; training; travel; treasure; tree; trophy; truck; try; Tuesday; tunnel; turn; turning; tv; type; umbrella; uncle; walk; walking; wall; van; war; warehouse; waste; watch; water; way; wedding; Wednesday; week; weekend; vegetable; whale; wheel; whistle; white; wife; village; wind; window; vine; wing; winter; witch; volcano; wolf; woman; wood; word; world; worm; worry; yard; year; yellow; zoo;

Nouns belonging to school level Year 2 (612 nouns):

ad; adult; aeroplane; afternoon; age; air; airport; alarm; ambulance; animal; ant; apple; arm; army; art; august; baby; back; bacon; badge; bag; ball; balloon; banana; bark; barn; basketball; bat; bathroom; battle; bay; beach; bear; bed; bedroom; beer; bench; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bone; book; boot; bottle; bowl; box; boy; boyfriend; bracelet; brain; bread; breakfast; bread; bridge; brother; brown; brush; bucket; building; bull; bunch; bus; butterfly; cake; camera; camp; camping; can; cancer; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; chain; chair; challenge; chat; chef; chest; chicken; chimney; chip; chocolate; choice; circle; city; class; classroom; climbing; clock; clothes; cloud; clown; club; code; coffee; cold; colour; competition; computer; container; contest; cook; cookie; cooking; cost; cottage; cough; country; court; cousin; cow; craft; crash; cream; creature; crew; cricket; crime; cross; crystal; cup; cupboard; dance; dancing; daughter; day; death; deer; desert; dessert; devil; diamond; diary; dinner; dinosaur; disco; distance; dog; doll; door; dream; dress; drink; drive; drop; duck; earth; elephant; enemy; engine; evening; evil; exercise; eye; face; factory; fair; fall; family; farm; fat; feeling; fence; field; fire; fish; fishing; flash; flight; floor; fly; fog; food; foot; football; force; forest; form; fox; frame; freezer; Friday; friend; frog; fruit; fuel; fun; funeral; fur; furniture; future; game; garden; gardening; gate; gear; ghost; girl; girlfriend; glass; glasses; goal; gold; golf; grass; grave; green; grey; ground; group; guard; guitar; gun; gymnastics; hair; haircut; ham; hand; hat; hate; head; heart; heat; hero; hill; hip; history; hole; holiday; home; homework; honey; hope; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; island; jacket; jail; jam; jar; jewellery; joy; judge; juice; jungle; junk; kangaroo; kettle; kick; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; laser; lawn; leaf; leader; leaf; leaf; leg; legend; lemon; lemonade; leopard; lesson; level; library; life; light; lightning; line; lion; living; loaf; log; lounge; love; lunch; luncheon; machine; mail; man; mango; march; mark; market; mask; master; matter; matter; may; meal; meat; mechanic; medal; medicine; mess; message; metal; metre; midnight; milk; mind; mirror; miss; Monday; money; monkey; monster; month; morning; mother; motor; motor; mouse; mouth; Mrs; mud; mum; museum; music; musical; mystery; name; nap; neck; necklace; need; news; newspaper; night; noise; nose; number; obstacle; ocean; october; opening; oven; pain; paint; pair; palace; paper; parade; parcel; parent; park; parrot; party; pasta; patch; peace; pen; pencil; penguin; people; person; pet; petrol; piano; pie; piece; pig; pillow; pin; pink; pirate; pizza; plan; planet; planning; plant; playground; point; pole; police; pony; present; president; prince; princess; prize; problem; professor; puppy; purple; push; rabbit; radio; rain; rainbow; rat; red; rescue; rest; restaurant; rice; river; road; robot; rock; rocket; roof; room; rope; round; rubber; run; running; sack; salad; sand; sandwich; Saturday; sausage; scarf; school; science; sea; seat; second; secret; seed; September; set; shape; shark; shed; sheep; sheet; ship; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; shower; side; silver; singer; sir; siren; skate; skeleton; skin; sky; sleep; smoke; snack; snake; snow; soldier; son; song; sound; soup; south; space; speed; spelling; spider; spoon; square; stable; stadium; stage; staircase; stairs; stand; star; step; stomach; storey; storm; story; strawberry; street; string; summer; sun; Sunday; sweets; tail; talk; tank; tea; teacher; teaching; team; teenager; temper; tent; thought; Thursday; tiger; timber; time; tin; toast; today; toe; toilet; tongue; tooth; top; torch; touch; towel; tower; town; toy; track; tractor; train; training; treasure; tree; triangle; trophy; trouble; truck; try; Tuesday; tunnel; turn; turning; tv; uncle; walk; walking; wall; van; war; wardrobe; warrior; waste; water; waterfall; wave; way; wedding; Wednesday; week; weekend; west; whale; wheel; whistle; white; video; wife; village; wind; window; vine; wing; winter; witch; volcano; wolf; woman; wood; wool; word; world; worry; writing; yard; year; yellow; zone; zoo;

Nouns belonging to school level Year 3 (825 nouns):

act; action; actor; ad; adult; adventure; aeroplane; afternoon; age; agent; air; airport; alarm; angel; animal; ankle; answer; ant; apartment; apple; area; arm; army; art; attention;

august; aunt; award; baby; back; backpack; bacon; bag; balcony; ball; ballet; balloon; banana; bandage; bark; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bear; beauty; bed; bedroom; beef; beer; behaviour; bench; bicycle; bike; bird; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; bottle; bowl; box; boxing; boy; boyfriend; brain; branch; bread; breakfast; breath; breed; brick; bridge; brother; brown; brush; bucket; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; carpet; carrot; cartoon; case; cash; castle; cat; cave; ceiling; cereal; chain; chair; challenge; champion; championship; chance; chat; cheese; chef; chest; chicken; child; chimney; chin; chip; chocolate; choice; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; club; coat; code; coffee; cold; collar; colour; comedy; comic; competition; computer; concert; cook; cookie; cooking; cost; costume; cottage; cough; country; courage; court; cousin; cow; crack; craft; crash; cream; creature; crew; cricket; crime; crisis; cross; crowd; crystal; cup; cupboard; cure; customs; dad; damage; dance; dancer; dancing; danger; darkness; dessert; detective; devil; diamond; diary; dinner; dinosaur; dirt; disaster; disco; disguise; distance; dog; doll; door; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; electricity; element; elephant; enemy; energy; engine; entrance; envelope; evening; evil; excitement; exercise; experiment; explosion; explosive; eye; face; fact; factory; fall; family; farm; fashion; fat; father; fear; feeling; fence; field; fight; figure; fire; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forest; fox; frame; friday; friend; frigate; frog; fruit; fun; funeral; fur; furniture; future; game; gang; garden; gas; gate; gear; ghost; girl; glass; glasses; goal; gold; golf; government; grandmother; grandson; grass; green; grey; grin; ground; group; guard; guide; guitar; gun; gym; gymnastics; hail; hair; hall; ham; hammer; hand; happiness; hat; hate; health; heart; heat; heaven; height; helicopter; hell; helmet; hero; hill; history; hole; holiday; home; homework; honey; hope; horn; horse; hospital; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; information; invasion; invention; island; jacket; jail; jam; jar; jazz; jeans; jewellery; journey; joy; juice; junk; kangaroo; kettle; kick; kid; killer; killing; king; kiss; kitchen; kite; kitten; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; lead; leader; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; library; life; light; lighting; lightning; line; lion; literacy; living; log; lounge; love; luck; luggage; lunch; luncheon; machine; mail; man; mango; mansion; map; march; mark; market; mask; master; mat; match; matter; may; meal; meat; medal; medicine; meeting; mess; message; metal; metre; midnight; milk; mind; minute; mirror; mist; mix; mixture; model; monday; money; monkey; monster; month; morning; mosquito; mouse; mouth; Mrs; mud; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; nest; news; newspaper; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; ocean; october; office; oil; onion; opening; oven; owner; pack; pain; paint; pair; palace; paper; parachute; parcel; parent; park; party; patch; pattern; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; performance; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; plumber; pocket; point; poison; pole; police; pony; post; poster; present; president; prince; princess; prison; prize; problem; professional; professor; project; property; protection; pulse; pump; punishment; puppy; purple; purse; push; puzzle; quest; question; quiet; quiz; rabbit; radio; railway; rain; rainbow; raincoat; rainforest; rat; realm; reason; recipe; rectangle; red; referee; remains; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; right; risk; river; road; robbery; robot; rock; rocket; roof; room; root; rope; rose; round; rubber; ruler; ruler; rumour; run; running; sack; saddle; safety; sail; salad; sand; sandwich; Saturday; sauce; saucer; sausage; saving; scar; scarf; school; science; scientist; scissors; screen; sea; season; seat; second; secret; security; seed; self; sense; September; series; servant; set; setting; shade; shadow; shame; shampoo; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; side; sign; silence; silver; simulation; singer; singing; sink; sir; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smile; smoke; snack; snake; snow; society; soldier; son; song; soul; sound; soup; south; souvenir; space; spade; species; speed; spelling; sphere; spider; spoon; sport; squad; square; stable; stadium; stage; staircase; stairs; stand; star; starvation; state; statue; steel; step; stick; stomach; stone; storey; storm; story; strawberry; stream; strength; stretch; strike; string; strong; style; success; sugar; suitcase; summer; summit; sun; Sunday; sunlight; sunset; sunshine; supermarket; surface; surfing; surgery; surroundings; sweat; sweet; sweets; switch; sword; system; tail; talk; talks; tank; taste; tea; teacher; teaching; team; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; test; theft; thief; thought; throat; throne; thunder; Thursday; tick; tide; tiger; tights; timber; time; tin; toast; today; toe; toilet; tomato; ton; tone; tongue; tooth; top; torch; tornado; torture; touch; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; training; transport; travel; treasure; tree; triangle; trip; trophy; trouble; truck; try; tube; Tuesday; tunnel; turn; turning; tv; twin; type; umbrella; uncle; university; waist; walk; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warrior; waste; watch; water; waterfall; wave; way; weapon; weather; webcam; wedding; Wednesday; weed; week; weekend; vegetable; vegetarian; weight; velvet; west; whale; wheat; wheel; whistle; white; widow; wife; village; wind; window; vine; wing; winner; winter; violence; wish; witch; volcano; wolf; volleyball; woman; wood; wool; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zoo;

Nouns belonging to school level Year 4 (1072 nouns):

accident; acid; act; action; actor; ad; adult; adventure; advertisement; aeroplane; afternoon; age; agent; air; airport; alarm; ambulance; amusement; analysis; angel; anger; animal; ankle; answer; ant; apartment; apple; april; arch; area; arm; army; art; attention; august; aunt; award; baby; back; backpack; bacon; badge; bag; balcony; ball; ballet; balloon; banana; bandage; bank; barn; baseball; basement; basket; basketball; bat; bathroom; battle; bay; beach; bear; behaviour; bench; bicycle; bike; bikini; bill; bird; birth; birthday; bit; bite; black; blanket; blood; blue; boat; body; bomb; bone; book; boost; boot; bottle; bow; bowl; box; boxing; boy; boyfriend; bracelet; brain; branch; bread; breakfast; breath; breed; breezer; brick; bridge; broom; brown; brush; bucket; budget; building; bull; bullet; bunch; bus; butter; butterfly; button; cabin; cake; camera; camp; camping; can; cancer; cap; car; career; carpet; carrot; cartoon; case; cash; castle; cat; cattle; cave; ceiling; celebration; cent; centimetre; century; cereal; ceremony; chain; chair; challenge; champion; championship; chance; channel; chat; cheek; cheese; chef; cherry; chest; chicken; child; chill; chimney; chin; chip; chocolate; choice; choir; circle; circus; city; class; classic; classroom; cliff; climbing; clinic; clock; cloth; clothes; clothing; cloud; clown; club; coat; code; coffee; cold; coldness; collar; colour; comedy; comfort; comic; competition; computer; concert; concrete; confidence; container; contest; conversation; cook; cookie; cooking; copper; cost; costume; cottage; cough; country; courage; court; cousin; cow; crack; craft; crash; cream; creature; crew; cricket; crime; crisis; cross; crowd; crystal; cup; cupboard; cure; customs; dad; damage; dance; dancer; dancing; danger; darkness; dash; daughter; day; death; deck; deer; description; desert; designer; dessert; detective; devil; diamond; diary; dictionary; dinosaur; dirt; disaster; discipline; disco; disguise; distance; distraction; dog; doll; dollar; door; doorway; drama; dream; dress; drink; drive; drop; drum; duck; duty; ear; earth; earthquake; east; elbow; election; electricity; element; elephant; emergency; enemy; energy; engine; entertainment; entrance; envelope; estate; evening; evil; exam; examination; excitement; exercise; experience; experiment; exploration; explosion; explosive; eye; face; fact; factory; fair; fall; family; farm; fashion; fat; father; fear; February; feeling; fence; festival; fever; field; fight; figure; fire; firm; fish; fishing; flash; flight; floor; flower; fly; fog; food; foot; football; force; forehead; forest; form; fountain; fox; frame; freedom; freezer; friday; friend; frigate; frog; fruit; fuel; fun; funeral; fur; furniture; future; game; gang; garden; gardening; gas; gate; gear; gender; ghost; girl; girlfriend; glass; glasses; glove; goal; goat; gold; golf; government; grandfather; grandmother; grandson; grasp; grass; grave; green; grey; grin; ground; group; guard; guitar; gun; gym; gymnastics; hail; hair; haircut; hall; ham; hammer; hand; handbag; happiness; harm; hat; hate; head; heading; headquarters; health; heart; heat; heater; heaven; heel; height; helicopter; hell; helmet; help; hero; hill; hip; history; hold; hole; holiday; home; homework; honey; hope; horn; horse; hospital; hostel; hotel; hour; house; hug; human; hunting; husband; ice; idea; imagination; independence; information; injury; insight; interview; invasion; invention; island; jacket; jail; jam; jar; jazz; jeans; jewel; jewellery; journey; joy; judge; juice; junk; kangaroo; kettle; kick; kid; killer; killing; king; kingdom; kiss; kitchen; kite; kitten; knee; knife; ladder; lady; lake; lamb; land; landing; lane; language; lap; laptop; laser; laugh; laughter; law; lawn; lead; leader; leaf; leak; learning; leg; legend; lemon; lemonade; leopard; lesson; lettuce; level; liberty; library; life; light; lighting; lightning; line; lion; liquid; literacy; litter; living; loaf; log; lottery; lounge; love; luck; luggage; lunch; luncheon; lyrics; machine; mail; male; man; mango; mansion; manual; map; march; mark; market; mask; master; mat; match; material; matter; may; meal; meat; mechanic; medal; medicine; meeting; mess; message; metal; metre; midnight; milk; mind; minute; mirror; misery; miss; mist; mix; mixture; musical; monday; money; monkey; monopoly; monster; month; morning; mosquito; mother; motor; mountain; mouse; mouth; Mrs; mud; mum; murder; murderer; muscle; museum; music; musical; mystery; name; nap; nation; nature; neck; necklace; need; neighbourhood; nephew; nerve; nest; news; newspaper; nickname; night; nightmare; noise; north; nose; note; notice; nuisance; number; object; obstacle; ocean; october; office; official; oil; onion; opening; opposite; orphan; oven; owner; pack; pain; paint; pair; palace; pants; paper; parachute; parade; paradise; parcel; parent; park; parrot; party; passage; passenger; passport; pasta; patch; patience; pattern; peace; peach; peak; peanut; pear; pen; pencil; penguin; people; performance; perfume; person; personality; pet; petrol; photo; piano; picnic; picture; pie; piece; pig; pillow; pin; pink; pirate; pitch; pizza; place; plan; planet; planning; plant; plastic; playground; pleasure; plumber; pocket; point; poison; pole; police; pony; post; poster; predator; present; president; pressure; price; prince; princess; prison; prize; problem; professional; professor; project; property; protection; pulse; pump; punishment; puppy; purple; purse; push; puzzle; quest; question; quiet; quiz; rabbit; radio; railway; rain; rainbow; raincoat; rainforest; rat; realm; reason; recipe; rectangle; red; referee; remains; reply; reporter; rescue; response; rest; restaurant; return; reward; revenge; ribbon; rice; right; risk; river; road; robbery; robot; rock; rocket; roof; room; root; rope; rose; round; rubber; ruler; ruler; rumour; run; running; sack; saddle; safety; sail; salad; sand; sandwich; Saturday; sauce; saucer; sausage; saving; scar; scarf; school; science; scientist; scissors; screen; sea; season; seat; second; secret; security; seed; self; sense; September; series; servant; set; setting; shade; shadow; shame; shampoo; shape; shark; shed; sheep; sheet; ship; shirt; shoe; shooting; shop; shopping; shore; shorts; shot; shoulder; show; shower; side; sign; silence; silver; simulation; singer; singing; sink; sir; siren; size; skate; skateboard; skateboarding; skeleton; ski; skiing; skill; skin; skull; sky; slap; slaughter; slave; sleep; slot; smile; smoke; snack; snake; snow; society; soldier; son; song; soul; sound; soup; south; souvenir; space; spade; species; speed; spelling; sphere; spider; spoon; sport; squad; square; stable; stadium; stage; staircase; stairs; stand; star; starvation; state; statue; steel; step; stick; stomach; stone; storey; storm; story; strawberry; stream; strength; stretch; strike; string; strong; style; success; sugar; suitcase; summer; summit; sun; Sunday; sunlight; sunset; sunshine; supermarket; surface; surfing; surgery; surroundings; sweat; sweet; sweets; switch; sword; system; tail; talk; talks; tank; taste; tea; teacher; teaching; team; technology; teenager; telescope; television; temper; temperature; temple; tennis; tent; test; theft; thief; thought; throat; throne; thunder; Thursday; tick; tide; tiger; tights; timber; time; tin; toast; today; toe; toilet; tomato; ton; tone; tongue; tooth; top; torch; tornado; torture; touch; tourist; tournament; towel; tower; town; toy; track; tractor; trade; traffic; trail; train; training; transport; travel; treasure; tree; triangle; trip; trophy; trouble; truck; try; tube; Tuesday; tunnel; turn; turning; tv; twin; type; umbrella; uncle; university; waist; walk; walking; wall; valley; van; war; wardrobe; warehouse; warmth; warrior; waste; watch; water; waterfall; wave; way; weapon; weather; webcam; wedding; Wednesday; weed; week; weekend; vegetable; vegetarian; weight; velvet; west; whale; wheat; wheel; whistle; white; widow; wife; village; wind; window; vine; wing; winner; winter; violence; wish; witch; volcano; wolf; volleyball; woman; wood; wool; word; world; worm; worry; vote; writer; writing; yard; year; yellow; zone; zoo;

Appendix AF

As discussed in Subchapter 12.2, we carried out random path explorations in hyperlink network of 25153 unique hyperlinks connecting 2878 unique nouns of vocabulary A1&A2&B1&B2&C1&C2 (based on English Vocabulary Profile) so that any hyperlink can be traversed in both actual linking direction and opposite direction and all explorations were started from concept Human (starting from concept Human was motivated by our earlier finding that among 69 shared concepts in hyperlink network of the Wikipedia concept Human has the highest number of occurrences as start or end concept as shown in Table 5.5). This listing shows the number of visits for each of 2878 unique concepts in a random path of 1000000 steps in descending order of the number of visits (the number of visits shown in parenthesis).

2878 unique nouns in 25153 unique hyperlinks connecting unique nouns of vocabulary A1&A2&B1&B2&C1&C2 supplied with the number of visits (shown in parenthesis) in a random path of 1000000 steps, when started from concept Human and allowing each hyperlink to be traversed in both actual linking direction and opposite direction, in descending order of the number of visits:

human (4404); water (3607); food (3037); animal (2765); psychology (2604); science (2520); philosophy (2470); earth (2378); nature (2376); culture (2374); mammal (2342); law (2286); agriculture (2187); religion (2169); evolution (2167); economics (2161); education (2123); entertainment (2087); plant (2037); government (2031); technology (1997); crime (1988); transport (1987); oxygen (1944); carbon dioxide (1934); globalization (1930); protein (1916); energy (1915); turkey (1910); bird (1891); business (1891); infrastructure (1875); mind (1863); sun (1861); time (1832); physics (1816); fish (1793); species (1790); music (1781); bacteria (1780); clothing (1738); medicine (1726); insect (1722); nutrition (1701); iron (1692); wood (1678); carbon (1672); cancer (1642); art (1633); biology (1627); god (1617); competition (1603); meat (1603); fruit (1601); history (1577); emotion (1569); literature (1567); death (1559); life (1547); chemistry (1523); society (1510); copper (1508); language (1508); politics (1439); engineering (1428); plastic (1424); wind (1420); shoe (1414); steel (1414); advertising (1413); skin (1396); money (1394); insurance (1390); light (1387); computer (1366); communication (1365); fear (1362); milk (1356); disease (1355); war (1354); knowledge (1348); information (1343); reality (1341); dna (1340); temperature (1337); sea (1327); horse (1325); leather (1325); film (1322); gold (1318); bone (1306); ecology (1302); toy (1297); house (1296); abuse (1289); health (1287); family (1285); suffering (1277); reason (1276); archaeology (1275); blood (1274); soil (1270); conscience (1267); aluminium (1264); red (1258); cattle (1256); vegetable (1254); sustainability (1243); painting (1223); genetics (1211); road (1203); television (1199); commerce (1198); perfection (1196); ship (1188); supermarket (1188); anger (1187); muscle (1186); geography (1182); theory (1180); economy (1178); kitchen (1176); extinction (1174); poetry (1172); metal (1169); gas (1167); civilization (1166); flower (1161); radio (1160); sheep (1159); global warming (1155); experiment (1152); trade (1151); perception (1150); tool (1148); scientist (1140); salt (1133); force (1127); silver (1123); capitalism (1122); door (1122); fat (1121); book (1114); paper (1114); soup (1114); silk (1113); cooking (1112); bread (1111); electricity (1110); science fiction (1109); weather (1109); machine (1101); city (1100); immune system (1096); virtue (1091); hierarchy (1087); leaf (1085); love (1085); reputation (1084); wine (1083); climate (1082); astronomy (1080); police (1077); sense (1074); density (1073); motivation (1073); self-esteem (1068); space (1066); property (1063); fire (1061); sausage (1059); planet (1057); matter (1054); profession (1052); gene (1049); university (1048); brain (1047); organization (1046); writing (1046); measurement (1043); statistics (1038); cotton (1037); narrative (1036); game (1035); heat (1034); sky (1034); creativity (1033); river (1032); lead (1030); seed (1030); dog (1029); future (1029); hunting (1029); market (1028); sugar (1027); tax (1027); employment (1025); liquid (1024); sunlight (1024); desert (1023); corporation (1021); construction (1018); atom (1016); consciousness (1016); artist (1015); fiction (1009); sound (1008); climate change (1005); ocean (1005); shark (1004); yellow (1004); experience (1003); recreation (1002); grass (1001); fashion (997); loneliness (995); risk (995); truth (991); sport (989); system (989); atmosphere (987); title (985); building (984); community (984); research (981); institution (980); writer (980); rice (977); chicken (975); human rights (974); airport (973); goat (973); garden (969); virus (967); butter (966); friendship (964); intelligence (962); famine (960); leadership (960); pollution (960); marriage (953); tiger (950); hobby (947); ice (944); gender (943); theatre (943); aircraft (941); digestion (940); pressure (938); heart (934); lake (932); learning (931); year (925); child (924); bat (922); snow (922); sculpture (921); perfume (920); wheat (918); novel (917); contract (910); rain (910); evaluation (907); reptile (907); logic (905); tobacco (903); day (902); cloud (893); erosion (892); school (888); rainforest (885); wealth (881); analogy (879); manufacturing (879); singing (879); green (873); pizza (873); violence (872); glass (871); burial (869); tree (866); architecture (863); woman (863); happiness (858); yogurt (854); mining (852);

terrorism (851); electronics (850); air conditioning (849); dance (849); recycling (849); adaptation (845); coal (842); camping (841); geology (841); cheese (838); coast (838); management (838); design (837); smoke (837); therapy (836); acid (834); honey (834); party (832); engine (831); invasion (831); hospital (829); alcohol (828); probability (826); commodity (823); swimming pool (823); torture (823); fishing (822); innovation (822); justice (822); flight (818); rabbit (818); x-ray (818); bronze (817); vitamin (815); wool (814); banana (810); dinosaur (806); tea (805); pink (804); beef (803); travel (803); tourism (801); idea (800); mask (800); pie (797); salad (797); mail (796); pain (793); infection (790); taste (790); anxiety (788); sex (788); hair (786); ozone (785); crocodile (784); observation (783); snake (782); democracy (781); friction (781); volcano (781); artificial intelligence (780); propaganda (779); health care (777); reproduction (776); spirit (776); drug (775); person (775); spice (775); wedding (775); cat (774); oak (774); image (771); industry (771); ownership (771); vehicle (771); white (771); museum (770); noun (769); walking (769); symbol (768); garlic (767); pet (757); rat (757); star (757); translation (757); flour (756); season (756); structure (755); adjective (754); fuel (754); liver (754); farm (753); laboratory (752); result (749); gift (748); potato (745); punishment (745); vinegar (745); coffee (744); obesity (742); public transport (739); pride (738); aggression (733); bed (732); data (730); racism (728); debt (727); lung (725); finance (724); elephant (723); professor (723); slavery (722); belief (719); photography (719); world (719); concrete (716); skeleton (713); liberty (712); teacher (711); father (710); concept (709); honour (709); hypothesis (708); feather (707); gardening (707); error (705); surgery (705); authority (704); roof (702); drought (701); ant (700); restaurant (699); revolution (698); disability (697); tomato (697); tragedy (694); black (692); stereotype (691); ritual (689); volume (687); dolphin (686); night (686); drink (685); blue (684); drama (684); landscape (683); homelessness (682); factory (680); currency (678); video game (678); emergency (677); grammar (677); memory (677); murder (677); controversy (675); lighting (675); produce (675); rocket (673); pottery (672); intellectual (671); bank (670); bus (669); tin (669); brass (667); habitat (667); marketing (667); bee (666); imagination (663); word (663); man (662); dust (661); evidence (661); mountain (661); sand (661); ambiguity (660); carbon monoxide (660); lion (659); male (659); flood (658); infant (658); celebrity (657); onion (657); privacy (657); stroke (657); wheel (657); air (652); brand (652); sleep (650); cholesterol (649); tradition (649); olive (648); beer (644); gambling (643); weapon (643); regulation (641); simulation (641); suicide (641); training (641); kidney (640); meal (638); retail (638); skill (638); jazz (637); parent (637); poverty (637); hygiene (636); storm (636); boy (635); consumer (634); economist (633); glove (632); clock (631); rope (630); spider (630); thought (630); month (625); beauty (624); crystal (623); deer (621); fast food (620); frog (620); safety (620); plan (618); solution (618); angel (617); train (617); park (615); camel (614); hand (614); philosopher (614); herb (613); craft (612); debate (611); envy (610); judge (609); pleasure (609); security (609); individual (608); peace (608); dream (607); female (606); kilogram (606); lightning (606); feedback (604); mirror (604); devil (602); rape (600); poison (599); jury (598); laser (598); summer (598); headache (597); mobile phone (597); prison (596); sign (596); mouse (595); cake (594); empathy (594); dessert (593); graphics (593); cereal (592); library (589); adult (587); wilderness (586); metaphor (585); birth (584); credit card (584); drawing (583); tongue (582); calendar (580); eye (580); region (579); autumn (578); cargo (578); soul (578); document (576); opera (576); investment (575); song (575); root (573); coin (572); verb (571); blog (570); body (570); jewellery (570); blade (568); existence (568); pea (568); stock (567); farmer (565); face (564); prediction (564); wisdom (564); resource (563); earthquake (562); mixture (562); pork (562); inflation (560); circle (559); luck (558); newspaper (558); criticism (555); heaven (555); knife (555); scissors (555); theft (555); question (554); predator (553); bear (552); reference (552); slang (552); evil (551); speech (551); immigration (550); nation (550); pregnancy (550); sphere (550); canal (549); linen (549); synonym (549); home (548); mat (546); parliament (546); understanding (543); injury (541); uncertainty (540); map (539); hotel (538); diamond (537); faith (536); ceremony (535); uniform (535); bicycle (531); fraud (531); soft drink (531); violin (531); curry (530); paint (530); apple (529); goal (529); office (529); toddler (529); constitution (528); performance (528); orchestra (527); professional (527); satellite (527); breakfast (526); bruise (526); cold (526); doubt (526); election (525); musician (525); sin (525); village (525); essay (524); thunderstorm (524); lawn (523); pig (523); baseball (522); company (518); fox (518); medal (518); metre (517); tail (517); wildlife (517); bridge (516); ink (515); prayer (515); president (515); oven (514); crop (513); board game (512); foot (512); lawyer (511); country (509); diplomacy (509); enemy (509); leisure (509); mother (509); socialism (509); ambulance (508); classroom (507); pharmacy (507); inheritance (506); omelette (506); town (506); border (505); robot (505); shirt (505); trail (505); integrity (504); blindness (501); concert (501); actor (500); childhood (500); audience (499); mosque (499); rose (498); asset (496); lemon (496); temple (494); college (493); apartment (492); cemetery (492); trousers (492); joke (490); dignity (488); population (488); fantasy (487); police officer (487); soap (487); stomach (486); tooth (486); court (484); funeral (484); lunch (484); disaster (483); furniture (483); proposition (483); skull (483); basketball (482); curtain (482); ice cream (482); spoon (481); tornado (481); carpet (480); interest (480); disco (479); sunset (479); telephone (479); battle (478); inquiry (478); team (478); area (477); disgust (477); complexity (476); lecture (476); towel (476); length (475); sailing (475); straw (475); wave (475); jealousy (474); lie (474); retirement (473); refugee (472); stream (471); invention (470); monopoly (470); crisis (469); flag (469); aspirin (468); window (468); explosion (467); material (467); mushroom (467); software (467); mosquito (465); waste (465); bacon (464); glasses (464); literacy (464); paradox (464); piano (464); rhythm (464); punctuation (463); curiosity (462); castle (459); monster (459);

comedy (458); pear (458); winter (458); chess (457); wheelchair (456); beard (455); engineer (455); expert (455); spreadsheet (454); generation (453); laughter (453); partnership (452); protest (452); shampoo (452); treaty (452); bark (450); fee (450); flame (450); website (450); medication (449); angle (448); deception (448); bomb (447); ghost (447); rainbow (447); speed (447); leopard (446); match (445); welfare (445); phenomenon (444); psychologist (444); street (444); coconut (443); cream (443); mango (443); hell (442); pine (442); riot (442); combat (441); cricket (441); materialism (441); nerve (441); runway (441); wire (441); washing machine (440); hatred (439); radiation (439); zoo (439); priest (438); sword (438); code (437); procession (437); tent (437); boot (436); housewife (435); humour (435); bag (433); beak (433); bean (433); cookie (433); unemployment (431); discrimination (429); paradise (429); polar bear (429); respect (428); sunglasses (428); button (427); fact (427); football (427); skirt (427); leak (426); pasta (426); crab (425); kite (425); parrot (425); smile (425); architect (424); beach (424); coral (424); cost (424); definition (424); grandparent (424); cash (423); harvest (423); saint (423); grape (422); argument (421); collaboration (421); starvation (421); rubber (420); arrest (419); embarrassment (419); offspring (419); student (417); tank (417); toilet (417); wasp (417); animation (416); candle (416); traffic (416); journalist (415); valley (415); ear (414); irony (414); leg (414); loan (414); noise (414); prime minister (414); truck (414); grey (413); hail (411); steam (411); strap (411); berry (410); tennis (409); tide (409); backpack (408); pillow (408); price (408); wife (408); grain (407); magistrate (407); oil (407); pump (407); camera (406); momentum (406); persuasion (406); pharmacist (405); spinach (405); detective (404); festival (404); intellect (404); chest (403); income (403); surface (403); policy (402); thermometer (402); exercise (401); strawberry (401); abortion (400); bottle (400); referendum (400); shame (400); wallet (400); peanut (399); republic (399); triangle (399); frost (398); bribery (397); doll (397); ice hockey (397); stock market (397); dice (396); nickname (396); brick (395); helicopter (394); pancake (394); prosecutor (394); sacrifice (394); port (393); storey (392); airline (391); cucumber (391); parachute (391); people (391); email (390); hero (390); nationality (390); particle (390); composer (389); donkey (389); tractor (389); whale (389); continent (386); label (386); nest (386); tunnel (386); cycling (383); running (383); shopping (383); patient (382); aid (381); household (381); sunrise (381); forest (380); shyness (380); project (379); tuna (379); dirt (378); sunday (378); fur (377); chocolate (376); database (376); fluid (376); cigarette (375); divorce (375); prejudice (375); cherry (374); tights (374); vandalism (374); analysis (373); blame (373); curriculum (373); video (373); official (372); opinion (372); ball (371); horizon (371); purple (371); wing (371); auction (370); navy (370); news (370); quantity (369); dvd (368); euro (368); addition (367); number (367); necklace (366); adverb (364); butterfly (364); knee (364); neck (364); salary (364); symptom (364); hazard (362); interaction (362); sadness (362); basement (361); chimney (361); fever (361); arrow (360); box (359); chef (359); chemist (359); soap opera (358); fog (357); helmet (357); problem (357); sauce (357); brown (356); cable (356); kiss (356); microphone (356); sail (356); vaccine (356); dress (355); status symbol (355); fair (354); juice (354); litre (354); lyrics (354); throne (354); twin (354); miracle (353); irritation (352); weight (352); awareness (351); gang (351); guitar (350); second (350); validity (350); pedestrian (349); weed (349); customer (348); rib (348); pastry (347); carrot (346); owl (346); revelation (346); antibiotic (345); height (345); laundry (345); telescope (345); chart (344); idiom (344); conversation (343); denim (343); rectangle (343); brush (342); exchange rate (342); hug (342); missile (342); mouth (342); cooperation (341); revenge (341); waist (341); formula (340); paradigm (340); bias (339); diagram (339); secondary school (339); west (339); firefighter (338); head (338); imitation (338); island (338); payment (338); sewing (338); illness (337); negotiation (337); peach (337); pyramid (337); ratio (337); revenue (337); cloth (336); insight (336); accident (335); gentleman (335); journalism (335); rescue (335); sweater (335); attention (334); cartoon (334); salmon (334); clown (333); emperor (333); photograph (333); sibling (333); vocabulary (333); landing (332); chair (331); fence (331); panic (330); penguin (330); proverb (330); magazine (329); vice (329); boat (328); exhibition (328); bite (327); girl (327); handbag (327); instinct (327); kangaroo (327); legend (327); surfing (327); ballet (325); cow (325); poster (324); rudeness (324); self-awareness (324); chemical (323); genius (323); traffic light (323); denial (322); feeling (322); rush hour (322); nose (321); presenter (321); worship (321); courage (319); hat (319); jargon (319); icon (318); plural (318); resort (318); saddle (317); suffix (316); cutlery (315); jacket (315); suburb (315); tribe (315); bakery (314); bullet (314); vaccination (314); wound (314); cathedral (313); vein (313); dimension (312); import (312); jam (312); peasant (312); tram (312); customs (311); junk food (311); studio (311); week (311); entity (310); longevity (310); blanket (309); insomnia (309); mansion (309); thunder (309); daylight (308); mud (308); soldier (308); jaw (307); pattern (307); pub (307); pupil (307); warrior (307); calf (306); portrait (306); county (305); donation (305); husband (305); scar (305); snack (305); cabbage (303); circus (303); biscuit (302); sandal (302); export (301); industrialization (301); referee (301); debit card (300); palace (300); techno (300); ancestor (299); baggage (299); humility (299); politician (299); choir (298); bathroom (297); branch (297); breast (297); grief (297); hammer (297); investor (297); optimism (297); gossip (296); saturday (296); sink (296); watch (296); apostrophe (295); career (295); cliff (295); corruption (295); umbrella (295); distance (294); hip (294); ferry (293); role (293); shower (293); giraffe (292); hall (292); lip (292); resentment (292); yacht (292); cod (291); illustration (291); golf (290); transportation (289); virtual reality (289); barn (288); reasoning (288); hope (287); webcam (287); vine (287); worm (287); bookcase (286); diary (286); living room (286); october (286); warehouse (286); worry (286); bay (285); birthday (285); bracelet (285); carbon footprint (285); funding (285); playground (285); pen (284); recession (284); november (283); barbecue

(282); prince (282); woodland (282); zebra (282); floor (281); peer pressure (280); province (280); review (280); wall (280); workshop (280); explanation (279); fly (279); monkey (279); robbery (279); shadow (279); t-shirt (279); rash (278); saving (278); steak (278); pension (277); ankle (276); ironing (276); souvenir (276); wage (276); alphabet (275); solitude (275); awe (274); butcher (274); disappointment (274); kindness (274); recruitment (274); costume (273); dawn (273); extract (273); sock (273); candidate (272); column (272); smoking (272); earring (271); nightmare (271); stadium (271); east (270); joint (270); lottery (270); melody (270); casserole (269); spectrum (269); bureaucracy (268); full stop (268); shorts (268); thursday (268); shield (267); ski (267); empire (266); hour (266); monument (266); neighbourhood (266); pity (266); army (265); carriage (265); cello (265); department store (265); desk (265); forgiveness (265); message (265); description (264); dialect (264); loft (262); logo (262); vegetation (261); balloon (260); common sense (260); duty (260); pencil (260); dialogue (259); brake (258); jeans (258); skateboarding (258); bride (257); chewing gum (257); cliché (257); contradiction (257); rhyme (257); shoulder (257); whistle (257); homework (256); assault (255); clause (255); elegance (255); mayor (255); pudding (255); sandwich (255); fireplace (254); loyalty (254); prosperity (254); shed (254); trophy (254); carnival (253); certainty (253); choice (253); gesture (253); destiny (252); historian (252); laptop (252); poet (252); ribbon (252); telecommunications (252); independence (251); boxing (250); harmony (250); switch (250); yard (250); harm (249); trial (249); van (249); central heating (248); dinner (248); ham (248); hyphen (248); morning (248); passport (248); digital camera (247); honesty (247); obstacle (247); railway (247); silence (247); eyelash (246); innocence (246); stupidity (246); smog (245); ton (245); volleyball (245); victory (244); addiction (243); consultant (243); selfishness (243); baker (242); convenience (242); bowl (241); eagle (241); gram (241); shape (241); holiday (240); march (240); coaching (239); precedent (239); room (239); author (238); cushion (238); hostage (238); principle (238); receptionist (238); surgeon (238); technician (238); toe (238); cd-rom (237); chapel (237); inch (237); solicitor (237); threat (237); dictionary (236); rebellion (236); skiing (236); pond (235); cough (234); friday (234); legislation (234); roundabout (234); witness (234); frying pan (233); leek (233); applause (232); output (232); passenger (232); snowboarding (232); cheque (231); club (231); exaggeration (231); millennium (231); name (231); whisky (231); award (230); comb (230); remote control (230); vanity (230); cupboard (229); flesh (229); hill (229); necessity (229); tournament (229); gymnastics (228); well-being (228); vowel (228); bestseller (227); disc jockey (227); inspector (227); pocket (227); lesson (225); parking (225); picnic (225); preposition (225); suspense (225); february (224); noon (224); phrase (224); shore (224); tomb (224); video clip (224); affection (223); cross (223); knot (223); main course (223); paw (223); son (223); teaspoon (223); comfort (222); toothbrush (221); duck (220); exploration (220); nightclub (220); subsidy (220); bit (219); essence (219); south (219); syllable (219); consideration (218); ladder (218); sympathy (218); xenophobia (218); barber (217); expense (217); wrist (217); cheek (216); protagonist (216); thesis (216); tick (216); acceptance (215); broccoli (215); laziness (215); mechanic (215); postcard (215); scrap (215); strategy (215); january (214); designer (213); illusion (213); lettuce (213); forgery (212); tutor (212); weekday (212); comedian (211); grave (211); line (211); marathon (211); veil (211); ceiling (210); century (210); flute (210); teaching (210); electrician (209); steering wheel (209); toast (209); audition (208); pineapple (208); contempt (207); negligence (207); preference (206); pulse (206); elite (205); generalization (205); burglary (204); garment (204); quotation (204); sir (204); wardrobe (204); sailor (203); vegetarian (203); answer (202); concentration (202); diploma (202); failure (202); north (202); relief (202); amusement (201); clinic (201); spouse (201); stairs (201); hedge (200); puzzle (200); relevance (200); demand (199); stocking (199); hockey (198); finger (197); hunger (197); password (197); chain (196); escalator (196); intention (196); nurse (195); slope (195); supervisor (195); adoption (194); diving (194); handkerchief (194); litter (194); singer (194); sleeve (194); waterfall (194); yoga (194); coincidence (193); minute (193); nonsense (193); alliance (192); breed (192); diplomat (192); poem (192); publicity (192); bull (191); dancing (191); pronoun (191); superlative (191); discipline (190); incentive (190); present (190); ruler (190); vow (190); advocate (189); dishwasher (189); may (189); receipt (189); acre (188); arm (188); implementation (188); planning (188); wit (188); memorial (187); catering (186); decade (186); nightlife (186); razor (186); shooting (186); confidence (185); gerund (185); guide (185); kilometre (185); count (184); intrusion (184); thumb (184); amateur (183); banking (183); fountain (183); monday (183); appeal (182); exclamation mark (182); group (182); sequence (182); snob (182); speculation (182); budget (181); bulb (181); campsite (181); scarf (181); anchor (180); badge (180); consent (180); greeting (180); kitten (180); soundtrack (179); swan (179); sweat (179); temptation (179); top (179); fluency (178); frustration (178); newsletter (178); prefix (178); nostril (177); cd player (176); centimetre (176); determiner (176); district (176); vocation (176); luggage (175); midnight (175); morale (175); penny (175); cure (174); size (174); stain (174); thigh (174); youth (174); biography (173); chin (173); event (173); journal (173); relish (173); wolf (173); attempt (172); mug (172); parade (172); trilogy (172); tv (172); hate (171); praise (171); promise (171); recipe (171); windsurfing (171); diagnosis (170); endurance (170); mist (170); suitcase (170); arrangement (169); tribute (169); anniversary (168); bun (168); ice skating (168); stable (168); wednesday (168); clutch (167); compromise (167); ignorance (167); enjoyment (166); imprisonment (166); semicolon (165); timber (165); velvet (165); workforce (165); benefit (164); envelope (164); lane (164); millimetre (164); patience (164); privilege (164); scholar (164); terrorist (164); adventure (163); mile (163); scarcity (163); credibility (162); fun (162); balcony (161); bedroom (161); calculator (161); cruelty (161); employer (160); eyebrow (160); hairdresser (160);

menu (160); toothpaste (160); farming (159); fisherman (159); iceberg (159); trumpet (159); discretion (158); drum (158); earnings (158); episode (158); fabric (158); self (158); uncle (158); affair (157); comma (157); gym (157); explosive (156); dishonesty (155); dissertation (155); consonant (154); gate (154); phrasal verb (154); quest (154); tourist (154); civilian (153); effectiveness (153); harassment (153); june (153); landlord (153); remorse (153); scenario (153); takeover (153); bus stop (152); committee (152); corn (152); moustache (152); set (152); appetite (151); need (151); web page (151); basket (150); complaint (150); crowd (150); disposition (150); duvet (150); primary school (150); statue (150); chest of drawers (149); complexion (149); guitarist (149); hypocrisy (149); syllabus (149); daughter (148); bikini (147); facility (147); generosity (147); percentage (147); baby (146); behaviour (146); eyelid (146); overdraft (146); tracksuit (146); chancellor (145); folk (145); landmark (145); myth (145); potential (145); torch (145); wrinkle (145); aunt (144); breath (144); confirmation (144); nomination (144); productivity (144); employee (143); hostel (142); workplace (142); blister (141); gun (141); pin (141); verdict (141); buyer (140); hostility (140); ingredient (140); king (140); retailer (140); citizen (139); frown (139); plumber (139); deodorant (138); girlfriend (138); popularity (138); brother-in-law (137); fare (137); police station (137); tuesday (137); air force (136); campus (136); comparative (136); forehead (136); gear (136); presentation (136); prostitute (136); question mark (136); veteran (136); consensus (135); headquarters (135); puppy (135); seminar (135); signature (135); socialist (135); teamwork (135); dash (134); lighter (134); self-confidence (134); climbing (133); evening (133); exile (133); prisoner (133); ambassador (132); commander (132); fork (132); gain (132); infinitive (132); personality (132); psychiatrist (132); amendment (131); bracket (131); critic (131); dentist (131); note (131); politeness (131); prize (131); august (130); crew (130); gardener (130); moonlight (130); toughness (130); social networking (129); arch (128); blackmail (128); prosecution (128); thirst (128); accountant (127); calculation (127); self-control (127); september (127); simplicity (127); alarm clock (126); likelihood (126); miss (126); shade (126); annoyance (125); championship (125); disguise (125); examination (125); mercy (125); odds (125); december (124); gallery (124); neglect (124); textbook (124); collocation (123); cousin (123); surname (123); backup (122); friend (122); nostalgia (122); volunteer (122); afternoon (121); classic (121); enthusiasm (121); pint (120); suspect (120); photographer (119); realm (119); reform (119); archaeologist (118); council (118); side effect (118); publication (117); courtesy (116); majority (116); spade (116); cave (115); cottage (115); slave (115); ordeal (114); criminal (113); gadget (113); quiz (113); spelling (113); workaholic (113); broadband (112); lady (112); meeting (112); programmer (112); questionnaire (112); blend (111); boyfriend (111); cd (111); cola (111); dining room (111); environmentalist (111); temper (111); curve (110); greed (110); novelty (110); selection (110); conviction (109); ground (109); vote (109); walk (108); container (107); novelist (107); antique (106); bus station (106); trend (106); café (105); pact (105); saucer (105); secretary (105); act (104); inspection (104); manufacturer (104); pair (104); sunshine (104); accuracy (103); drawback (103); kit (103); presumption (103); racist (103); summit (103); supporter (103); agreement (102); cause (102); distraction (102); elbow (102); interview (102); dilemma (101); sincerity (101); trekking (101); album (100); blackboard (100); cap (100); jail (100); weather forecast (100); injustice (99); inventor (99); badminton (98); bucket (98); orphan (98); slap (98); snowboard (98); statistic (98); touch (98); july (97); land (97); lecturer (97); mineral water (97); pole (97); right (97); talk (97); sweet (96); withdrawal (96); occupation (94); raid (94); squad (94); staircase (94); success (94); widow (94); era (93); fibre (93); firework (93); knuckle (93); paragraph (93); petrol (93); recording (93); seat (93); efficiency (92); favourite (92); pronunciation (92); april (91); debit (91); exchange (91); hospitality (91); table tennis (91); underwear (91); purse (90); deck (89); groom (89); shop (89); square (89); vase (89); handout (88); insult (88); loaf (88); melon (88); nap (88); partner (88); sister-in-law (88); bill (87); heel (87); infancy (87); lemonade (87); mrs (86); origin (86); report (86); reporter (86); strength (86); toothache (86); car (85); coup (85); dj (85); requirement (85); teenager (85); allegation (84); machinery (84); researcher (84); tray (84); vest (84); entertainer (83); hip-hop (83); responsibility (83); treasure (83); booking (82); frenzy (82); kick (82); obligation (82); rehearsal (82); rule (82); stone (82); adolescent (81); colour (81); disagreement (81); discussion (81); judgment (81); madam (81); notebook (81); post office (81); side (81); skate (81); seller (80); sentiment (80); willpower (80); dedication (79); repair (79); sack (79); series (79); unrest (79); contestant (78); dislike (78); pony (78); renovation (78); surroundings (78); darkness (77); department (77); firm (77); immigrant (77); input (77); mp3 player (77); cleaner (76); availability (75); champagne (75); commercial (75); documentary (75); idiot (75); impossibility (75); pan (75); slogan (75); brother (74); determination (74); fight (74); grandmother (74); bandage (73); champion (73); fall (73); headline (73); nuisance (73); pay (73); terror (73); width (73); boss (72); component (72); counter (72); institute (72); issue (72); specification (72); vitality (72); device (71); heritage (71); massacre (71); nerves (71); piece (71); recollection (71); tuition (71); advertisement (70); fortnight (70); princess (70); regime (70); celebration (69); crackdown (69); murderer (69); point (69); roommate (69); sensibility (69); throat (69); trip (69); confusion (68); misery (68); publisher (68); rest (68); status (68); unit (68); contribution (67); materialist (67); raincoat (67); solidarity (67); heating (66); motorway (66); sightseeing (66); spam (66); witch (66); bribe (65); clothes (65); disadvantage (65); frontier (65); jungle (65); lap (65); picture (65); skateboard (65); trouble (65); backpacker (64); download (64); kettle (64); expenses (63); hard drive (63); inclination (63); member (63); pensioner (63); saying (63); trash (63); usage (63); fist (62); growth (62); honeymoon (62); pack (62); protection (62); remedy (62); study (62); trainee (62); bookmark (61); dancer (61); degree (61); equation (61); figure (61); virgin (61); camp (60); case

(60); charisma (60); freezer (60); grandfather (60); grill (60); individuality (60); investigation (60); leader (60); redevelopment (60); spokesperson (60); sweatshirt (60); pirate (59); text (59); average (58); content (58); edition (58); greatness (58); mr (58); response (58); underpants (58); bomber (57); first language (57); object (57); scratch (57); weekend (57); difficulty (56); midday (56); narrator (56); possibility (56); progression (56); spite (56); track (56); brochure (55); class (55); fingernail (55); graph (55); loss (55); pc (55); station (55); stimulus (55); story (55); supervision (55); threshold (55); collar (54); defeat (54); deprivation (54); organ (54); production (54); reception (54); sheet (54); supper (54); trace (54); ad (53); commitment (53); creation (53); custom (53); discomfort (53); glue (53); goalkeeper (53); qualification (53); reply (53); comic (52); coverage (52); minority (52); omission (52); peak (52); smoker (52); survival (52); bow (51); intensity (51); intruder (51); itinerary (51); lorry (51); model (51); performer (51); suggestion (51); waiter (51); chance (50); complex (50); joy (50); masterpiece (50); premises (50); return (50); siren (50); slaughter (50); stage (50); weakness (50); aeroplane (49); agent (49); channel (49); chat (49); disc (49); drop (49); enterprise (49); jug (49); level (49); proximity (49); record (49); terrace (49); traffic jam (49); uncountable (49); change (48); church (48); delegate (48); extreme sports (48); jar (48); officer (48); setting (48); embrace (47); exam (47); grasp (47); housing (47); link (47); niece (47); openness (47); phone (47); round (47); rumour (47); strike (47); sum (47); task (47); treat (47); tube (47); delegation (46); dustbin (46); heater (46); host (46); id card (46); insecurity (46); preservation (46); proof (46); remains (46); residence (46); restraint (46); treatment (46); attribute (45); back (45); captain (45); cast (45); claim (45); form (45); jogging (45); log (45); plea (45); savings (45); sector (45); signal (45); ability (44); crash (44); definite article (44); drawer (44); exposure (44); granny (44); lunchtime (44); nervousness (44); post (44); resignation (44); screen (44); style (44); wish (44); barrier (43); card (43); decision (43); disposable income (43); drive (43); horn (43); instructor (43); investigator (43); notice (43); photo (43); show (43); sister (43); substance (43); tenderness (43); toenail (43); alarm (42); capital (42); contraception (42); corpse (42); coward (42); harbour (42); meaning (42); motion (42); motorist (42); movie (42); outbreak (42); place (42); pullover (42); run (42); self-discipline (42); spy (42); bank account (41); capacity (41); coat (41); entrance (41); heir (41); intent (41); labour (41); pants (41); presidency (41); skating (41); technique (41); characteristic (40); check (40); lounge (40); personnel (40); pop (40); preparation (40); prey (40); scandal (40); tower (40); environment (39); junk (39); merger (39); mortality (39); penalty (39); shopkeeper (39); sorrow (39); state (39); string (39); tranquility (39); turn (39); admiration (38); challenge (38); coldness (38); confession (38); fake (38); fragrance (38); purpose (38); sickness (38); sponsorship (38); staff (38); stop (38); assembly (37); draft (37); emission (37); flu (37); fortune (37); quote (37); relation (37); timetable (37); upgrade (37); coastline (36); magic (36); nephew (36); owner (36); reflection (36); rival (36); voyage (36); desire (35); desktop (35); mode (35); secret (35); terminal (35); the internet (35); descendant (34); equal (34); shot (34); simplification (34); fate (33); grandpa (33); heading (33); heart attack (33); leaflet (33); mystery (33); scholarship (33); self-respect (33); exhibit (32); guarantee (32); intervention (32); opportunity (32); opposite (32); sensation (32); site (32); text message (32); win (32); clash (31); competitor (31); limitation (31); plot (31); procedure (31); reign (31); cultivation (30); delight (30); effort (30); element (30); facilities (30); feast (30); guidance (30); resilience (30); tone (30); vet (30); worker (30); bombing (29); conservation (29); course (29); disk (29); grandma (29); installation (29); jumper (29); loathing (29); representation (29); ruling (29); telly (29); amount (28); bench (28); bookshelf (28); conference (28); cyclist (28); delivery (28); disrespect (28); doom (28); field (28); master (28); observer (28); occurrence (28); ornament (28); passage (28); servant (28); theme (28); alcoholic (27); bang (27); cell (27); doorway (27); enquiry (27); equipment (27); fame (27); indication (27); kilo (27); letter (27); push (27); source (27); spark (27); stepmother (27); tension (27); user (27); windscreen (27); account (26); action (26); administration (26); blogger (26); breakthrough (26); comeback (26); concern (26); confrontation (26); contraceptive (26); correction (26); dad (26); effect (26); fighting (26); frame (26); grandson (26); housework (26); journey (26); miner (26); mobile (26); musical (26); pause (26); quarrel (26); runner (26); slot (26); sufferer (26); tip (26); villager (26); addict (25); car park (25); care (25); companion (25); cup (25); cut (25); deputy (25); dump (25); expenditure (25); integration (25); jewel (25); kingdom (25); living (25); make-up (25); mum (25); order (25); pace (25); page (25); policeman (25); prawn (25); rank (25); recovery (25); resolution (25); shuttle (25); strand (25); test (25); travel agent (25); union (25); warmth (25); view (25); attachment (24); band (24); cheerfulness (24); client (24); clue (24); collection (24); contest (24); diver (24); donor (24); granddad (24); improvement (24); instruction (24); isolation (24); killing (24); launch (24); liability (24); mankind (24); mark (24); message board (24); mix (24); move (24); rage (24); rate (24); role model (24); shelter (24); tale (24); talks (24); trek (24); advantage (23); assistance (23); boundary (23); break (23); capital letter (23); cellar (23); circulation (23); cook (23); core (23); destination (23); distinction (23); dive (23); edge (23); embassy (23); flash (23); follower (23); gamble (23); humanity (23); importance (23); instrument (23); jump (23); learner (23); martial art (23); northeast (23); operation (23); patch (23); persistence (23); policewoman (23); purity (23); request (23); stamina (23); successor (23); tour (23); whim (23); worst (23); zone (23); allowance (22); background (22); backpacking (22); board (22); bottom (22); bunch (22); burglar (22); charge (22); consequence (22); consumption (22); contents (22); convention (22); danger (22); detail (22); distress (22); dominance (22); expedition (22); freedom (22); handle (22); hold (22); knob (22); mess (22); optimist (22); period (22); possession (22); prevention (22); rating (22); rebel (22); reserve (22); restriction (22); reversal (22); rise (22); schoolchild (22); schooling (22); stall (22); standard (22); store (22);

strip (22); subtitles (22); support (22); therapist (22); thief (22); try (22); assumption (21); assurance (21); bike (21); breeze (21); carelessness (21); casualty (21); colleague (21); conflict (21); conversion (21); crack (21); credit (21); cv (21); damage (21); daycare (21); deal (21); doctor (21); fairness (21); fire station (21); goodness (21); guilt (21); kind (21); lover (21); misunderstanding (21); painter (21); parcel (21); pastime (21); pence (21); petrol station (21); priority (21); provider (21); retreat (21); roll (21); saucepan (21); score (21); single (21); singular (21); specialist (21); spokesman (21); stick (21); taxpayer (21); timing (21); tune (21); type (21); undertaking (21); vision (21); athletics (20); boost (20); catastrophe (20); chill (20); conclusion (20); corridor (20); creature (20); decoration (20); deficiency (20); desperation (20); habit (20); haircut (20); initiative (20); killer (20); lamb (20); lid (20); measure (20); mention (20); pot (20); rail (20); resident (20); reward (20); richness (20); salesman (20); storage (20); stretch (20); supplier (20); talent (20); turning (20); unhappiness (20); youngster (20); ache (19); bug (19); can (19); coach (19); control (19); disruption (19); function (19); fund (19); guard (19); handwriting (19); idol (19); indefinite article (19); interpretation (19); lab (19); load (19); mechanism (19); part (19); player (19); proposal (19); rock (19); row (19); rug (19); scent (19); self-assurance (19); sweets (19); target (19); way (19); verse (19); accent (18); application (18); cabin (18); campaign (18); click (18); diet (18); dose (18); draught (18); establishment (18); grin (18); gum (18); keeper (18); manager (18); manual (18); parallel (18); principal (18); refund (18); stand (18); today (18); trait (18); ward (18); advice (17); age (17); chip (17); competence (17); conception (17); diesel (17); disorder (17); dot (17); duration (17); excuse (17); eyesight (17); flat (17); fool (17); fright (17); granddaughter (17); landlady (17); mine (17); minimum (17); panel (17); photocopy (17); reach (17); reading (17); rugby (17); serial (17); sitting room (17); smell (17); step (17); troops (17); banker (16); bargain (16); bond (16); booklet (16); courgette (16); cycle (16); echo (16); exit (16); fault (16); grandchild (16); guest (16); initial (16); kid (16); laugh (16); motor (16); proceedings (16); recognition (16); relaxation (16); riches (16); rubbish (16); setback (16); advert (15); aspiration (15); bet (15); bin (15); charm (15); combination (15); dispute (15); eagerness (15); excitement (15); help (15); key (15); native speaker (15); pitch (15); rivalry (15); survey (15); tour guide (15); walker (15); impatience (14); quiet (14); refuge (14); spread (14); appointment (13); cent (13); decline (13); estate (13); hardware (13); hesitation (13); liar (13); local (13); motive (13); overtime (13); pool (13); tablet (13); turnover (13); inspiration (12); query (12); resistance (12); signpost (12); thinker (12); bravery (11); identity (11); membership (11); recruit (11); unity (11); winner (11); graduate (10); comment (0); direction (0); directions (0); end (0); ending (0); exhaust (0); exhaustion (0); hole (0); network (0); networking (0); northwest (0); opening (0); program (0); programme (0); register (0); registration (0); remark (0); resemblance (0); scene (0); scenery (0); similarity (0); southeast (0); superior (0); superiority (0); term (0); terms (0); will (0); willingness (0);

Appendixes AG

In hyperlink network of articles belonging to Wikipedia category Malta in June 2014 containing 35688 unique hyperlinks we identified the shortest paths. From concept Tourism in Malta to concept Maltese euro coins there are 29 alternative shortest paths having length of three hyperlinks and after exclusion of paths traversing concept Malta there are 11 alternative shortest paths which are all shown here supplied with relation statements we generated for each hyperlink.

<i>Concept</i>	<i>Relation statement for hyperlink connecting concepts</i>	<i>Concept</i>	<i>Relation statement for hyperlink connecting concepts</i>	<i>Concept</i>	<i>Relation statement for hyperlink connecting concepts</i>	<i>Concept</i>
tourism in Malta	forms about 15 percent of	economy of Malta	before year 2008 relied on money system of	lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta	made in years 1973-2007 money called	lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	offers popular beach holidays at	Gozo	is an island with important role in	history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta	are soldiers known to use symbol called	cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta	are important people starting from year 1530 in	history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta	about wars typically deals with	history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta	about visual identity typically mentions	official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	focuses on history at	Valletta	is a well protected living place since year 1566 in	history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	focuses on history at	Valletta	is a city shown in banknotes of year 1989 for	lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta

Appendixes AH

Based on Appendix AG this is listing of each of 22 unique hyperlinks with its sentence and shows the number coding that we used to create different orderings and variations of these sentences for text material used for silent reading task as well as pre-test and post-test for both experiment group and control group.

Identification number code for each of 22 unique hyperlinks	Sentence for each of 22 unique hyperlinks			Which alternative (A/B/C/D) in corresponding multiple-choice item of this sentence in the correct answer
	<i>Start concept</i>	<i>Relation statement</i>	<i>End concept</i>	
1	cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta	B
2	economy of Malta	before year 2008 relied on money system of	lira of Malta	D
3	government of Malta	made in years 1973-2007 money called	lira of Malta	C
4	Gozo	is an island with important role in	history of Malta	B
5	history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta	A
6	knights of Malta	are soldiers known to use symbol called	cross of Malta	C
7	knights of Malta	are important people starting from year 1530 in	history of Malta	C
8	knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta	C
9	lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta	A
10	Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta	B
11	official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta	D
12	overview of Malta	about wars typically deals with	history of Malta	D
13	overview of Malta	about visual identity typically mentions	official state symbol of Malta	C
14	tourism in Malta	forms about 15 percent of	economy of Malta	C
15	tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta	B
16	tourism in Malta	offers popular beach holidays at	Gozo	D
17	tourism in Malta	benefits from architecture made by	knights of Malta	A
18	tourism in Malta	goes to see traditional fishing at	Marsaxlokk	A
19	tourism in Malta	is an important industrial sector when talking about	overview of Malta	C
20	tourism in Malta	focuses on history at	Valletta	B
21	Valletta	is a well protected living place since year 1566 in	history of Malta	B
22	Valletta	is a city shown in banknotes of year 1989 for	lira of Malta	A

Appendixes A1

For members of the experiment group (n=24) the series of 62 sentences that was shown during silent reading task of each of three learning sessions (for each of three learning sessions the series of 62 sentences was identical). Here 62 sentences were chained in such an ordering that corresponds to traversing cumulatively a series of associative trails leading from concept Tourism in Malta to concept Maltese euro coins along alternative parallel shortest paths in hyperlink network of Wikipedia category Malta.

Figure 10.2 illustrates the ordering of the series of 62 sentences for experiment group. So the idea of this ordering is to first introduce the first hyperlink step for each of 11 shortest paths leading from concept Tourism in Malta to concept Maltese euro coins, next to introduce the second hyperlink step for each of 11 shortest paths, then to introduce the third hyperlink step for each of 11 shortest paths, and after that finally to introduce one by one the full routes of each of 11 shortest paths (thus showing three consecutive hyperlink steps belonging to each of 11 shortest paths).

tourism in Malta	forms about 15 percent of	economy of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
tourism in Malta	offers popular beach holidays at	Gozo
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	focuses on history at	Valletta
tourism in Malta	focuses on history at	Valletta
economy of Malta	before year 2008 relied on money system of	lira of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
Gozo	is an island with important role in	history of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
overview of Malta	about wars typically deals with	history of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
Valletta	is a well protected living place since year 1566 in	history of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	forms about 15 percent of	economy of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	offers popular beach holidays at	Gozo
Gozo	is an island with important role in	history of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta

history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
overview of Malta	about wars typically deals with	history of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	focuses on history at	Valletta
Valletta	is a well protected living place since year 1566 in	history of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	focuses on history at	Valletta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta

Appendixes AJ

This listing shows six different multiple-choice questionnaires that were used for pre-tests 1-3 and post-tests 1-3 (i.e. measurements 1-6) for both members of experiment group and members of control group. These pre-tests 1-3 and post-tests 1-3 (that we also call as measurements 1-6) contained always the same 22 multiple-choice items, each item corresponding to each of 22 unique hyperlinks (shown in Appendix AH) and having four alternative answers we had created so that only one of them is correct.

Each of six multiple-choice questionnaires given during exploration task have different randomized ordering for 22 multiple-choice items (but in each multiple-choice item the four answer alternatives and their ordering always remain the same in each of six questionnaires).

We show here in original layout only multiple-choice questionnaire for measurement 1 (supplied with a list of identification number coding matching with Appendix AH for each of 22 unique hyperlinks) and multiple-choice questionnaires for measurements 2-6 are described here only with lists of identification number coding.

Multiple-choice questionnaire for measurement 1 (i.e. pre-test 1):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 17, 22, 14, 11, 8, 4, 19, 20, 10, 16, 13, 18, 5, 9, 7, 1, 12, 15, 6, 2, 21, 3. Correct answers are shown in Appendix AH.

tourism in Malta	benefits from architecture made by	knights of Malta	A
tourism in Malta	benefits from literature made by	knights of Malta	B
tourism in Malta	benefits from road network made by	knights of Malta	C
tourism in Malta	benefits from innovations made by	knights of Malta	D
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta	A
Valletta	is a mountain shown in banknotes of year 1989 for	lira of Malta	B
Valletta	is a flower shown in banknotes of year 1989 for	lira of Malta	C
Valletta	is a river shown in banknotes of year 1989 for	lira of Malta	D
tourism in Malta	forms about 10 percent of	economy of Malta	A
tourism in Malta	forms about 12 percent of	economy of Malta	B
tourism in Malta	forms about 15 percent of	economy of Malta	C
tourism in Malta	forms about 17 percent of	economy of Malta	D
official state symbol of Malta	is an image for coins of 1-10 cents in	euro coins of Malta	A
official state symbol of Malta	is an image for coins of 1-50 cents in	euro coins of Malta	B
official state symbol of Malta	is an image for coins of 5-50 cents in	euro coins of Malta	C
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta	D
knights of Malta	was in years 1944-1975 mentioned in decoration of	official state symbol of Malta	A
knights of Malta	was in years 1944-1985 mentioned in decoration of	official state symbol of Malta	B

knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta	C
knights of Malta	was in years 1964-1985 mentioned in decoration of	official state symbol of Malta	D
Gozo	is a city with important role in	history of Malta	A
Gozo	is an island with important role in	history of Malta	B
Gozo	is a mountain with important role in	history of Malta	C
Gozo	is a house with important role in	history of Malta	D
tourism in Malta	is an important sector for crime when talking about	overview of Malta	A
tourism in Malta	is an important support for sport events when talking about	overview of Malta	B
tourism in Malta	is an important industrial sector when talking about	overview of Malta	C
tourism in Malta	is an important source for pollution when talking about	overview of Malta	D
tourism in Malta	focuses on nature at	Valletta	A
tourism in Malta	focuses on history at	Valletta	B
tourism in Malta	focuses on shopping at	Valletta	C
tourism in Malta	focuses on sports at	Valletta	D
Marsaxlokk	is a valley shown in banknotes of year 1986 for	lira of Malta	A
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta	B
Marsaxlokk	is a bird shown in banknotes of year 1986 for	lira of Malta	C
Marsaxlokk	is a lake shown in banknotes of year 1986 for	lira of Malta	D
tourism in Malta	offers popular skiing holidays at	Gozo	A
tourism in Malta	offers popular cooking holidays at	Gozo	B
tourism in Malta	offers popular mountain holidays at	Gozo	C
tourism in Malta	offers popular beach holidays at	Gozo	D
overview of Malta	about tourist attractions typically mentions	official state symbol of Malta	A
overview of Malta	about language usage typically mentions	official state symbol of Malta	B
overview of Malta	about visual identity typically mentions	official state symbol of Malta	C
overview of Malta	about school system typically mentions	official state symbol of Malta	D
tourism in Malta	goes to see traditional fishing at	Marsaxlokk	A
tourism in Malta	goes to see traditional skiing at	Marsaxlokk	B
tourism in Malta	goes to see traditional agriculture at	Marsaxlokk	C
tourism in Malta	goes to see traditional dancing at	Marsaxlokk	D
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta	A
history of Malta	tells that joining money system of EU in year 2007 introduced	euro coins of Malta	B
history of Malta	tells that joining money system of EU in year 2006 introduced	euro coins of Malta	C
history of Malta	tells that joining money system of EU in year 2005 introduced	euro coins of Malta	D
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta	A
lira of Malta	was a money system that was replaced in year 2006 by	euro coins of Malta	B
lira of Malta	was a money system that was replaced in year 2004 by	euro coins of Malta	C
lira of Malta	was a money system that was replaced in year 2002 by	euro coins of Malta	D
knights of Malta	are important people starting from year 1510 in	history of Malta	A
knights of Malta	are important people starting from year 1520 in	history of Malta	B
knights of Malta	are important people starting from year 1530 in	history of Malta	C
knights of Malta	are important people starting from year 1540 in	history of Malta	D
cross of Malta	is an image for coins of 0,50-2 euros in	euro coins of Malta	A

cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta	B
cross of Malta	is an image for coins of 0,01-0,50 euros in	euro coins of Malta	C
cross of Malta	is an image for coins of 0,10-0,50 euros in	euro coins of Malta	D
overview of Malta	about politics typically deals with	history of Malta	A
overview of Malta	about geography typically deals with	history of Malta	B
overview of Malta	about art typically deals with	history of Malta	C
overview of Malta	about wars typically deals with	history of Malta	D
tourism in Malta	since year 2010 contains adventure tourism recommended by	government of Malta	A
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta	B
tourism in Malta	since year 2010 contains nature tourism recommended by	government of Malta	C
tourism in Malta	since year 2010 contains sports tourism recommended by	government of Malta	D
knights of Malta	are soldiers known to use weapon called	cross of Malta	A
knights of Malta	are soldiers known to use strategy called	cross of Malta	B
knights of Malta	are soldiers known to use symbol called	cross of Malta	C
knights of Malta	are soldiers known to use church called	cross of Malta	D
economy of Malta	before year 2005 relied on money system of	lira of Malta	A
economy of Malta	before year 2006 relied on money system of	lira of Malta	B
economy of Malta	before year 2007 relied on money system of	lira of Malta	C
economy of Malta	before year 2008 relied on money system of	lira of Malta	D
Valletta	is a well protected living place since year 1564 in	history of Malta	A
Valletta	is a well protected living place since year 1566 in	history of Malta	B
Valletta	is a well protected living place since year 1568 in	history of Malta	C
Valletta	is a well protected living place since year 1570 in	history of Malta	D
government of Malta	made in years 1953-2007 money called	lira of Malta	A
government of Malta	made in years 1953-2002 money called	lira of Malta	B
government of Malta	made in years 1973-2007 money called	lira of Malta	C
government of Malta	made in years 1973-2002 money called	lira of Malta	D

Multiple-choice questionnaire for measurement 2 (i.e. post-test 1):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 14, 6, 2, 5, 20, 18, 22, 12, 8, 10, 19, 3, 15, 1, 17, 4, 9, 13, 11, 21, 7, 16. Correct answers are shown in Appendix AH.

Multiple-choice questionnaire for measurement 3 (i.e. pre-test 2):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 7, 20, 14, 18, 1, 12, 16, 3, 5, 21, 2, 6, 11, 4, 15, 19, 22, 10, 9, 8, 13, 17. Correct answers are shown in Appendix AH.

Multiple-choice questionnaire for measurement 4 (i.e. post-test 2):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 20, 4, 9, 15, 8, 2, 16, 21, 3, 12, 19, 5, 17, 13, 18, 11, 14, 6, 10, 7, 22, 1. Correct answers are shown in Appendix AH.

Multiple-choice questionnaire for measurement 5 (i.e. pre-test 3):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 9, 14, 15, 3, 22, 8, 10, 2, 18, 6, 21, 7, 16, 11, 5, 20, 19, 4, 13, 1, 17, 12. Correct answers are shown in Appendix AH.

Multiple-choice questionnaire for measurement 6 (i.e. post-test 3):

Ordering of multiple-choice items based on identification number coding shown in Appendix AH for each of 22 unique hyperlinks: 4, 11, 13, 5, 8, 21, 10, 19, 3, 18, 15, 2, 17, 12, 7, 6, 20, 22, 1, 14, 16, 9. Correct answers are shown in Appendix AH.

Appendixes AK

This listing shows three different series of 62 sentences having randomized ordering that were used for silent reading task of members of control group. In contrast with the experiment group (see Appendix AI), for members of the control group (n=10) the series of 62 sentences was made to have randomized ordering of sentences for each of three learning sessions. The idea of this randomization is to enable comparison of control group with experiment group which becomes in each three learning sessions exposed to the series of 62 sentences in such chained ordering that corresponds to traversing cumulatively a series of associative trails leading from concept Tourism in Malta to concept Maltese euro coins along alternative parallel shortest paths in hyperlink network.

The series of 62 sentences for silent reading task of learning session 1 for control group:

knights of Malta	are important people starting from year 1530 in	history of Malta
tourism in Malta	forms about 15 percent of	economy of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	offers popular beach holidays at	Gozo
tourism in Malta	focuses on history at	Valletta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	focuses on history at	Valletta
Valletta	is a well protected living place since year 1566 in	history of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	offers popular beach holidays at	Gozo
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
overview of Malta	about wars typically deals with	history of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	focuses on history at	Valletta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	forms about 15 percent of	economy of Malta
Gozo	is an island with important role in	history of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
overview of Malta	about wars typically deals with	history of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
Gozo	is an island with important role in	history of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
Valletta	is a well protected living place since year 1566 in	history of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta

history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
tourism in Malta	focuses on history at	Valletta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	benefits from architecture made by	knights of Malta

The series of 62 sentences for silent reading task of learning session 2 for control group:

tourism in Malta	forms about 15 percent of	economy of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
tourism in Malta	forms about 15 percent of	economy of Malta
Gozo	is an island with important role in	history of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
knights of Malta	are soldiers known to use symbol called	cross of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	focuses on history at	Valletta
knights of Malta	are important people starting from year 1530 in	history of Malta
overview of Malta	about wars typically deals with	history of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
Gozo	is an island with important role in	history of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
Valletta	is a well protected living place since year 1566 in	history of Malta
tourism in Malta	focuses on history at	Valletta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
overview of Malta	about wars typically deals with	history of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta

tourism in Malta	is an important industrial sector when talking about	overview of Malta
Valletta	is a well protected living place since year 1566 in	history of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
tourism in Malta	focuses on history at	Valletta
tourism in Malta	focuses on history at	Valletta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
tourism in Malta	offers popular beach holidays at	Gozo
tourism in Malta	benefits from architecture made by	knights of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
tourism in Malta	offers popular beach holidays at	Gozo
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta

The series of 62 sentences for silent reading task of learning session 3 for control group:

history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
overview of Malta	about wars typically deals with	history of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	since year 2010 contains medical tourism recommended by	government of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
tourism in Malta	offers popular beach holidays at	Gozo
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
overview of Malta	about wars typically deals with	history of Malta
Valletta	is a well protected living place since year 1566 in	history of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
tourism in Malta	benefits from architecture made by	knights of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
Marsaxlokk	is a village shown in banknotes of year 1986 for	lira of Malta
tourism in Malta	goes to see traditional fishing at	Marsaxlokk
tourism in Malta	focuses on history at	Valletta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
Valletta	is a city shown in banknotes of year 1989 for	lira of Malta
knights of Malta	was in years 1964-1975 mentioned in decoration of	official state symbol of Malta
cross of Malta	is an image for coins of 1-2 euros in	euro coins of Malta
government of Malta	made in years 1973-2007 money called	lira of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	benefits from architecture made by	knights of Malta
overview of Malta	about visual identity typically mentions	official state symbol of Malta
knights of Malta	are important people starting from year 1530 in	history of Malta
tourism in Malta	offers popular beach holidays at	Gozo
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	focuses on history at	Valletta
tourism in Malta	forms about 15 percent of	economy of Malta
Gozo	is an island with important role in	history of Malta
tourism in Malta	forms about 15 percent of	economy of Malta
tourism in Malta	focuses on history at	Valletta
economy of Malta	before year 2008 relied on money system of	lira of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta

official state symbol of Malta	is an image for coins of 10-50 cents in	euro coins of Malta
tourism in Malta	focuses on history at	Valletta
Valletta	is a well protected living place since year 1566 in	history of Malta
economy of Malta	before year 2008 relied on money system of	lira of Malta
knights of Malta	are soldiers known to use symbol called	cross of Malta
lira of Malta	was a money system that was replaced in year 2008 by	euro coins of Malta
tourism in Malta	is an important industrial sector when talking about	overview of Malta
Gozo	is an island with important role in	history of Malta
history of Malta	tells that joining money system of EU in year 2008 introduced	euro coins of Malta

Appendixes AL

This listing shows each of unique 22 pairs of consecutive hyperlinks that exist along the eleven shortest paths leading from concept Tourism in Malta to concept Euro coins of Malta.

Each pair of consecutive hyperlinks is listed here with identification number coding that corresponds to each of 22 unique hyperlinks (shown in Appendix AH):

14&2, 15&3, 16&4, 17&6, 17&7, 17&8, 18&10, 19&12, 19&13, 20&21, 20&22, 2&9, 3&9, 4&5, 6&1, 7&5, 8&11, 10&9, 12&5, 13&11, 21&5, 22&9.

Appendixes AM

Before the exploration experiment started we asked with this background questionnaire each student to report her gender and age as well as how easy it is for her to adopt knowledge through reading and how successfully she performs at school (see Table 10.18, Table 10.19 and Table 10.20). The two last mentioned questions were replied by selecting a most suitable answer from a scale of five given alternatives.

Background questionnaire:

Full name (first name and last name):

Age:

“How easy it is for you to adopt (=learn) new knowledge through reading?”

Very easy

Easy

Moderate

Difficult

Very difficult

“In your opinion, how successfully do you perform at school?”

Excellently

Well

Satisfactorily

Fairly

Faintly

Appendix AN

This is full listing about how members of experiment group and members of control group answered to each of six multiple-choice questionnaires and what background information was gathered about these persons. In all parts of this Appendix AN identical identification codes refer always to the same unique person.

Background information about members of experiment group and members of control group:

Explanation for notation:

N/A = not available.

Experiment group				
Identification code (person)	Gender	Age	How easy it is for you to adopt (=learn) new knowledge through reading?	In your opinion, how successfully do you perform at school?
E1	M	16	3	3
E2	M	16	3	2
E3	F	15	3	3
E4	F	15	3	3
E5	F	15	2	1
E6	M	16	3	2
E7	M	16	3	3
E8	F	15	2	3
E9	F	17	2	2
E10	F	17	2	2
E11	F	18	2	3
E12	F	15	2	2
E13	M	15	2	2
E14	F	15	3	2
E15	F	16	3	2
E16*	M	N/A	N/A	N/A
E17	F	16	2	2
E18	M	16	3	3
E19	F	17	2	2
E20	F	19	3	3
E21	F	17	3.5	2.5
E22*	M	N/A	N/A	N/A
E23*	M	N/A	N/A	N/A
E24	F	18	2	2
One of persons E16/E22/E23 has provided following information: 18, 1, 1				
Control group				
Identification code (person)	Gender	Age	How easy it is for you to adopt (=learn) new	In your opinion, how successfully do you

			knowledge through reading?	perform at school?
C1	F	17	2	2
C2	F	15	3	3
C3	M	17	3	2
C4	F	16	3	3
C5	F	17	2	3
C6	M	18	3	3
C7	F	19	2	2
C8	F	15	2	2
C9	F	15	2	1
C10	F	15	3	2

How members of experiment group and members of control group answered to each of six multiple-choice questionnaires:

Explanation for notation:

1=A, 2=B, 3=C, 4=D, 0=no answer, 9=unclearly indicated answer, 99=multiple answers.

How easy it is for you to adopt (=learn) new knowledge through reading?

1=Very easy, 2=Easy, 3=Moderate 4=Difficult, 5=Very difficult

In your opinion, how successfully do you perform at school?

1=Excellently, 2=Well, 3=Satisfactorily, 4=Fairly, 5=Faintly.

Person	Measurement 1 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
	1	2	3	2	4	3	2	2	3	4	3	2	2	3	2	0	1	1	2	2	3	1
E1	1	2	3	2	4	3	2	2	3	4	3	2	2	3	2	0	1	1	2	2	3	1
E2	2	2	3	2	1	2	2	2	2	3	2	3	2	3	2	3	1	3	4	3	2	3
E3	4	2	1	3	2	3	3	2	3	2	3	1	4	3	4	1	1	4	3	4	4	2
E4	3	3	1	2	2	3	2	2	1	4	3	3	3	4	4	4	1	1	2	4	3	1
E5	3	3	1	3	2	3	4	3	1	4	2	3	3	4	1	4	1	1	3	3	1	1
E6	2	1	1	3	4	4	1	2	4	3	2	2	1	1	1	3	1	2	3	3	4	2
E7	2	3	4	1	2	4	4	3	2	3	4	3	1	3	2	4	4	4	3	2	2	1
E8	1	1	3	3	4	2	4	1	3	4	2	4	2	2	3	3	0	1	4	1	3	1
E9	4	1	2	2	1	2	2	2	1	3	2	2	1	3	3	4	1	3	3	1	3	3
E10	3	2	2	1	2	3	3	2	2	4	1	2	1	4	3	3	1	1	4	2	1	1
E11	3	3	1	1	2	3	1	2	2	2	4	4	3	4	1	4	4	3	3	1	4	1
E12	2	1	3	3	1	3	2	3	3	4	4	2	0	3	3	3	1	1	3	2	2	1
E13	4	2	2	3	3	3	3	2	2	2	2	2	1	3	3	3	3	1	4	2	2	1
E14	2	2	2	3	4	2	2	3	2	2	4	2	0	2	1	3	1	4	3	2	3	1
E15	3	3	1	1	3	3	4	3	2	1	2	2	1	4	2	4	1	3	3	1	3	1
E16	9	4	4	2	9	3	9	2	1	3	9	2	9	9	1	4	9	3	4	9	2	1
E17	4	2	3	1	3	3	4	3	2	2	4	1	1	4	3	4	2	3	4	2	1	2
E18	0	0	0	2	0	2	0	0	4	2	0	2	2	4	1	0	3	0	0	0	0	0
E19	1	4	1	1	1	3	3	2	1	4	2	4	1	4	1	4	1	3	3	2	4	1
E20	2	4	1	1	1	1	3	2	1	2	3	2	3	4	1	4	1	3	3	3	1	4
E21	1	3	4	2	2	3	3	3	2	4	2	2	1	3	3	4	1	3	2	1	3	1

1																						
E2 2	2	2	3	2	3	3	1	1	2	4	2	4	3	2	3	4	4	1	1	2	3	1
E2 3	3	1	2	3	1	1	3	1	2	1	2	3	2	1	2	3	1	1	4	1	4	1
E2 4	3	4	3	3	3	3	1	1	1	2	2	1	1	2	3	4	1	4	3	2	2	4
Pe rso n	Measurement 1 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
C1	2	4	3	2	1	3	4	3	1	2	3	3	1	4	4	4	1	4	3	2	2	1
C2	4	4	4	1	2	1	3	1	1	3	3	2	1	2	3	1	1	4	3	1	2	2
C3	1	3	4	3	4	1	1	4	3	2	2	3	3	3	2	4	1	0	3	1	1	2
C4	2	3	3	2	1	1	4	2	3	2	2	1	2	3	3	3	2	3	1	3	2	2
C5	4	2	4	3	2	3	0	2	3	1	1	2	3	4	3	1	1	0	2	2	1	1
C6	3	2	4	1	4	3	3	2	4	2	2	2	3	3	3	4	3	3	3	3	4	1
C7	2	4	1	1	1	3	3	1	1	2	1	2	1	4	4	1	3	2	2	4	3	1
C8	3	4	1	2	1	3	3	3	1	3	2	2	1	3	3	4	1	1	3	1	2	3
C9	0	4	1	3	1	3	2	0	1	1	2	3	3	4	1	1	4	3	4	2	2	2
C1 0	3	4	1	3	3	2	2	2	2	2	3	2	1	3	3	3	1	3	3	2	4	2
Pe rso n	Measurement 2 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
E1	2	4	3	2	1	3	4	2	2	2	3	3	1	3	2	4	1	1	3	2	0	1
E2	3	2	3	2	4	2	3	3	2	3	3	3	3	1	3	3	1	3	2	3	2	2
E3	2	4	2	1	1	3	2	4	1	2	4	1	3	3	1	4	4	1	3	2	4	1
E4	2	3	1	2	1	3	4	3	1	2	4	4	1	2	2	4	1	1	3	2	3	1
E5	2	4	1	1	1	3	3	4	1	4	4	4	3	3	2	4	1	1	3	2	1	1
E6	2	1	2	1	1	3	3	4	4	99	2	2	1	3	1	4	2	4	1	2	4	2
E7	2	4	3	2	1	3	3	3	1	2	4	3	1	3	1	4	4	1	3	2	3	1
E8	2	4	1	2	1	3	3	1	1	4	2	4	3	3	2	4	1	1	1	2	2	1
E9	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E1 0	1	1	2	1	1	3	2	2	2	1	4	2	3	3	1	1	4	1	4	2	2	1
E1 1	2	4	3	2	1	3	3	3	1	4	4	4	3	3	2	4	1	1	3	2	2	1
E1 2	2	4	3	2	1	3	0	3	1	2	4	4	1	3	3	4	1	1	3	2	2	1
E1 3	2	4	1	2	1	3	2	4	1	2	4	1	1	3	0	4	1	1	3	2	2	1
E1 4	2	4	1	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E1 5	4	4	1	1	1	3	1	3	1	2	4	3	1	2	1	4	1	1	3	2	1	1
E1 6	2	4	3	2	1	3	3	1	1	4	1	2	3	2	4	4	1	1	3	2	4	1
E1 7	2	4	3	2	1	3	3	4	1	2	2	4	1	4	2	4	1	1	3	1	2	1
E1 8	2	4	3	2	0	3	0	1	1	0	4	1	1	3	2	4	0	0	3	2	0	0
E1 9	2	4	1	2	1	3	3	1	1	4	3	4	1	3	2	4	4	1	3	2	2	1
E2 0	4	4	1	1	1	3	3	3	1	2	2	4	3	3	2	4	1	1	3	2	3	1
E2 1	2	4	4	2	1	3	3	3	1	4	4	1	3	3	3	4	1	1	3	1	3	1
E2 2	2	4	1	2	1	3	3	2	1	2	4	4	3	3	2	4	1	1	3	2	2	1

E23	1	4	1	4	4	2	3	2	2	1	1	4	1	3	1	1	1	1	2	2	3	4
E24	2	4	3	3	1	3	2	3	1	2	2	4	3	3	2	4	1	1	3	2	1	1
Person	Measurement 2 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH																					
C1	2	4	1	2	1	3	4	4	1	2	4	4	1	3	2	4	1	1	4	2	4	1
C2	2	4	1	2	1	3	2	3	1	2	4	2	1	3	1	4	1	3	2	2	3	1
C3	4	4	4	3	1	1	3	3	4	2	2	3	3	3	1	1	2	1	0	2	4	3
C4	2	1	1	3	0	3	3	1	1	4	4	4	3	3	2	3	1	2	3	2	2	1
C5	1	4	2	1	1	3	2	2	2	1	4	2	3	3	1	1	4	1	4	2	2	1
C6	2	4	2	2	4	3	3	4	1	1	2	1	1	3	2	4	1	1	3	2	2	4
C7	2	4	3	2	1	3	3	3	1	4	1	4	3	3	2	4	1	1	3	2	1	1
C8	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
C9	2	4	3	1	1	3	2	3	1	2	4	2	1	3	2	1	1	1	4	2	3	1
C10	2	4	2	2	1	3	3	3	1	2	2	2	1	3	3	3	1	3	3	2	4	2
Person	Measurement 3 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH																					
E1	2	4	3	2	1	3	0	2	3	2	3	2	1	3	4	2	1	1	3	2	4	4
E2	2	2	2	3	3	2	4	1	3	2	3	4	4	1	1	2	1	1	3	3	2	2
E3	4	4	3	2	1	1	0	4	1	0	4	2	2	3	2	4	1	0	3	2	3	1
E4	2	3	1	2	1	3	1	3	1	2	4	2	1	2	2	4	1	1	3	2	1	1
E5	2	4	3	1	1	3	3	4	1	4	4	4	3	3	2	4	1	1	3	2	1	1
E6	2	2	1	2	4	4	2	1	1	4	1	3	2	1	2	1	3	4	1	3	1	3
E7	2	4	3	2	1	3	3	3	1	2	4	3	1	3	3	4	1	1	2	2	3	1
E8	2	4	1	2	1	3	2	1	1	4	2	4	2	3	2	1	1	1	2	1	3	1
E9	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E10	2	4	4	3	1	3	3	1	1	2	3	2	1	3	2	4	1	1	3	2	2	1
E11	2	4	3	2	1	3	3	3	1	4	4	4	3	3	2	4	1	1	3	2	2	1
E12	2	4	3	2	1	3	1	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E13	4	4	1	2	1	3	2	2	1	2	4	2	3	3	3	4	1	1	3	2	2	1
E14	2	4	4	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E15	4	4	1	1	1	3	4	2	1	2	4	2	3	2	1	3	1	3	3	2	3	1
E16	2	3	1	2	1	3	3	1	1	4	1	1	3	1	1	4	1	3	3	1	4	1
E17	2	4	3	2	1	3	3	3	1	2	4	4	1	3	2	4	1	1	3	1	3	1
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E19	1	4	3	2	1	3	3	2	1	4	3	4	1	3	2	4	4	1	3	2	2	1
E20	2	4	1	1	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	3	1
E21	2	4	4	2	1	3	3	3	1	4	4	1	3	3	3	4	1	1	3	1	3	1
E22	2	4	3	2	1	3	3	1	1	2	4	4	3	3	2	4	1	1	3	2	1	1
E23	1	4	2	2	3	3	3	3	4	1	1	2	1	3	1	2	1	1	2	3	2	1
E24	2	4	1	2	2	3	2	2	1	3	3	4	3	3	2	4	1	1	3	2	2	1

Person	Measurement 3 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
C1	2	4	3	2	1	3	3	1	1	2	4	4	1	3	2	4	1	1	4	2	3	1
C2	4	4	3	2	1	3	1	3	1	1	4	2	1	3	2	4	1	3	3	2	3	1
C3	2	4	1	4	1	2	2	3	3	0	3	3	2	3	3	4	1	1	2	1	1	1
C4	2	4	1	2	1	3	3	3	1	0	4	2	1	3	3	3	2	1	3	2	2	1
C5	3	1	4	3	1	3	4	2	2	1	1	1	4	2	1	1	3	3	2	1	3	1
C6	2	4	9	2	4	3	3	4	1	4	3	2	3	4	3	4	1	1	3	2	3	1
C7	2	4	3	2	1	3	3	3	1	4	1	1	3	3	2	4	1	1	3	4	1	1
C8	2	4	3	2	1	3	3	1	1	2	4	4	1	3	2	4	1	1	3	2	2	1
C9	2	4	3	1	1	3	2	3	1	2	2	2	1	3	2	1	1	1	3	2	3	1
C10	3	4	4	2	1	3	3	2	1	3	2	2	1	3	3	3	1	3	3	1	4	2
Person	Measurement 4 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
E1	2	4	3	2	1	3	4	3	1	4	3	2	1	3	3	4	1	1	2	2	3	3
E2	2	1	3	2	2	4	3	2	2	2	2	1	2	2	2	3	3	2	2	3	2	3
E3	4	4	4	2	1	2	3	3	1	4	4	0	3	3	2	4	1	3	3	1	2	2
E4	2	4	1	2	1	3	4	2	1	2	4	2	1	3	2	4	1	1	3	2	4	1
E5	2	4	1	2	1	3	3	3	1	4	4	4	3	3	2	4	1	1	3	2	2	1
E6	1	4	3	2	1	4	3	3	1	1	2	2	2	2	2	2	1	1	4	2	2	4
E7	2	4	1	2	1	3	3	2	1	2	4	3	1	3	2	4	4	1	2	2	3	2
E8	2	4	3	2	1	3	3	3	1	2	2	4	3	3	2	1	1	1	3	1	2	1
E9	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E10	2	3	2	2	1	3	2	3	1	2	4	3	3	3	2	3	1	3	3	2	2	3
E11	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E12	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E13	4	4	3	2	1	3	1	2	1	2	4	2	1	3	2	4	1	1	2	2	2	1
E14	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E15	2	4	1	2	1	3	1	3	1	2	4	4	3	3	2	3	1	1	3	2	2	1
E16	2	3	1	2	1	3	3	1	1	2	4	2	3	3	2	4	1	1	3	2	1	1
E17	2	4	3	2	1	3	3	3	1	2	4	4	1	3	2	4	1	1	3	2	2	1
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E19	2	4	3	2	1	3	3	3	1	4	4	4	3	3	2	4	1	1	3	2	2	1
E20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E21	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E22	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	3	1
E23	2	4	1	4	3	3	3	3	1	3	4	1	1	3	1	3	1	1	0	2	4	3
E24	2	3	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	1	1
Person	Measurement 4 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
C1	2	4	1	2	1	3	4	4	1	2	4	4	1	3	2	4	1	1	3	2	2	1
C2	2	4	1	2	1	3	3	3	1	2	4	4	1	3	2	4	1	3	3	1	2	1

C3	1	4	1	2	1	3	3	3	1	2	3	2	1	4	1	4	1	3	3	2	3	3
C4	2	4	3	3	1	3	1	1	1	2	3	3	4	3	2	1	1	2	3	2	1	3
C5	3	1	1	3	2	0	4	2	1	4	2	1	3	3	1	1	1	3	3	2	3	2
C6	2	1	3	2	4	3	1	3	1	2	1	2	3	3	2	4	1	1	3	2	3	3
C7	2	4	3	2	1	3	3	3	1	2	2	4	3	3	2	4	1	1	3	2	2	1
C8	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
C9	2	4	3	1	1	3	2	3	1	2	4	4	1	3	2	4	1	1	3	2	1	1
C10	2	4	3	2	1	2	3	3	1	2	2	2	3	3	3	4	0	1	3	2	3	2
Person	Measurement 5 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH																					
E1	2	4	3	2	1	3	4	3	1	2	3	2	2	3	3	4	1	1	2	2	3	1
E2	2	3	1	2	3	1	2	99	2	9	3	2	2	2	3	4	1	3	2	3	4	2
E3	4	4	4	2	1	3	3	3	1	2	4	1	3	3	2	1	1	1	1	1	2	1
E4	2	3	0	2	1	3	3	0	1	2	4	2	1	3	2	4	1	1	3	2	2	1
E5	2	4	3	2	1	3	3	3	1	4	4	2	3	3	2	4	1	1	3	2	2	1
E6	1	4	1	1	1	3	3	3	1	1	2	1	3	2	3	4	2	4	3	1	4	3
E7	2	4	1	2	1	3	4	3	1	2	4	2	1	3	1	4	4	1	2	2	3	1
E8	2	4	3	2	1	3	3	3	1	2	2	1	3	3	2	1	1	1	3	1	2	1
E9	2	4	3	2	1	3	3	3	1	2	4	1	3	3	2	4	1	1	3	2	2	1
E10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E11	2	4	3	2	1	3	3	3	1	2	4	2	3	3	2	4	1	1	3	2	2	1
E12	2	4	3	2	1	3	3	3	1	2	4	2	3	3	2	4	1	1	3	2	2	1
E13	2	4	3	2	1	3	3	2	1	2	4	2	2	3	2	4	1	1	3	2	2	1
E14	2	4	3	2	1	3	3	3	1	2	4	2	3	3	2	4	1	1	3	2	2	1
E15	2	4	1	1	1	3	1	3	1	2	4	1	3	3	2	4	1	1	3	1	2	1
E16	2	4	1	2	1	3	3	1	1	4	4	2	3	3	2	4	1	1	3	2	4	1
E17	2	4	3	2	1	3	3	3	1	2	4	2	1	3	2	4	1	1	3	2	2	1
E18	4	4	1	2	1	3	0	0	1	2	4	0	1	3	2	4	0	0	3	0	0	1
E19	1	4	3	2	1	3	3	3	1	4	3	2	3	3	2	4	1	1	3	2	2	1
E20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E21	2	4	3	2	1	3	3	3	1	2	4	1	3	3	2	4	1	1	3	2	2	1
E22	2	4	1	2	1	3	3	3	1	2	4	2	3	3	2	4	1	1	3	2	3	1
E23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E24	2	4	1	2	2	3	3	1	1	2	4	2	3	3	2	4	1	1	3	2	4	1
Person	Measurement 5 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH																					
C1	2	4	1	2	1	3	4	4	1	2	4	2	3	3	2	4	1	1	3	2	2	1
C2	2	4	3	0	1	3	3	3	1	2	4	1	1	3	2	4	1	3	3	2	3	1
C3	1	4	1	4	3	1	3	3	2	2	3	1	3	3	4	4	3	1	0	3	3	3
C4	2	4	1	2	1	3	3	3	1	1	4	2	2	3	2	4	1	1	1	2	2	2
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

C6	2	4	2	2	1	3	3	3	1	2	1	2	1	3	2	4	1	1	3	2	3	1
C7	2	4	3	2	1	3	3	3	1	2	1	2	3	3	2	4	1	1	3	2	2	1
C8	2	4	3	2	1	3	3	3	1	2	4	2	3	3	2	4	1	1	3	2	2	1
C9	2	4	3	1	1	3	2	3	1	2	4	3	1	3	2	1	4	1	1	2	1	1
C10	2	4	1	2	1	2	3	3	1	2	4	2	3	3	2	4	1	1	3	2	1	1
Person	Measurement 6 for Experiment group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
E1	2	4	1	2	1	3	4	3	1	2	4	4	3	3	4	4	1	1	2	2	3	1
E2	2	1	3	3	3	4	2	2	2	4	1	2	2	3	3	2	3	9	4	1	2	3
E3	4	4	3	2	1	1	3	3	0	2	4	4	3	3	2	4	1	2	1	1	2	1
E4	2	3	3	2	1	3	3	9	1	2	4	2	1	3	2	4	1	1	3	2	1	1
E5	2	4	1	2	1	3	3	3	1	2	4	4	3	3	2	4	0	1	3	2	2	1
E6	2	4	3	2	9	2	3	2	1	4	2	2	1	2	3	4	4	1	3	1	4	2
E7	2	4	1	2	1	3	4	3	1	2	4	3	1	3	1	4	4	1	2	2	3	1
E8	2	4	3	2	1	3	3	3	1	2	2	4	3	3	2	4	1	1	3	1	2	1
E9	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E11	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E12	2	4	3	2	1	1	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E13	4	4	3	2	1	3	2	3	1	2	4	3	2	3	2	4	1	1	3	2	2	1
E14	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E15	2	4	1	1	1	3	3	3	1	2	4	4	1	3	2	4	1	1	3	1	2	1
E16	2	4	3	2	1	3	3	1	1	4	4	2	3	3	1	4	1	1	3	2	4	1
E17	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E18	2	4	1	2	1	3	4	3	1	1	4	0	1	3	2	4	1	1	3	2	1	1
E19	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E21	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
E22	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	3	1
E23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E24	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	1	1
Person	Measurement 6 for Control group: Answers to 22 multiple-choice items (multiple-choice items shown here from left to right in order 1-22 based on ordering of identification number coding of 22 unique hyperlinks as shown in Appendix AH)																					
C1	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1
C2	2	4	3	2	1	3	3	3	1	1	4	4	3	3	2	4	1	1	3	1	2	1
C3	1	4	4	2	1	4	2	4	2	3	1	1	1	1	1	3	2	1	2	4	1	2
C4	2	4	4	2	1	3	3	3	1	3	4	2	3	3	1	1	1	1	2	2	1	3
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C6	2	4	2	2	1	3	3	3	1	2	2	2	3	3	3	4	1	1	3	2	3	1
C7	2	4	3	2	1	3	3	3	1	2	2	4	3	3	2	4	1	1	3	2	2	1
C8	2	4	3	2	1	3	3	3	1	2	4	4	3	3	2	4	1	1	3	2	2	1

C9	2	4	3	1	1	3	3	3	1	2	4	4	1	3	2	1	1	1	1	2	2	1
C10	0	4	3	2	1	0	3	3	1	2	4	4	3	3	2	4	1	1	3	0	2	0

In the end of multiple-choice questionnaire of measurement 6 there were these three additional questions to be answered:

Explanation for notation:

In your opinion how well do you understand English language?

1=Excellently, 2=Well, 3=Satisfactorily, 4=Fairly, 5=Faintly.

How easy it is for you to adopt (=learn) new knowledge through reading?

Before starting this experiment how much did you know about information shown during this experiment about Malta?

1=Very much, 2=Much, 3=Moderately, 4=Little, 5=Very little.

N/A=not available

Experiment group			
Person	In your opinion how well do you understand English language?	How many years you have studied English at school?	Before starting this experiment how much did you know about information shown during this experiment about Malta?
E1	2	4	4
E2	3	10	2
E3	2	8	5
E4	2	4	2
E5	2	13	4
E6	N/A	N/A	5
E7	2	13	1
E8	2	9	5
E9	2	11	4
E10			
E11	2	12	5
E12	2	8	4
E13	2	13	5
E14	2	8	5
E15	2	6	4
E16*	2	10	2
E17	2	10	5
E18	N/A	N/A	N/A
E19	2	8	5
E20			
E21	2.5	8	5
E22*	1	8	3
E23*	N/A	N/A	N/A
E24	2	11	5
Control group			
Person	In your opinion how well do you understand English language?	How many years you have studied English at school?	Before starting this experiment how much did you know about information shown during this experiment about Malta?

C1	1	8	5
C2	N/A	N/A	N/A
C3	5	A bit	5
C4	3	8	5
C5	N/A	N/A	N/A
C6	2	Possibly 9	5
C7	2	12	5
C8	2	9	4
C9	2	8	5
C10	2	13	4
One of persons C2/C5 has provided following information: 3, 9, 5			

Appendixes AO–AW

Reprints of the original publications [P1]–[P9] and supplements for publications [P2], [P5], [P6] and [P7] are available on the following pages.