A note on organizational learning and knowledge sharing in the context of communities of practice

Learning Networks for Lifelong Competence Development

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TEN Competence

Building The European Network for Lifelong Competence Development

INTERNATIONAL WORKSHOP

Learning Networks for Lifelong Competence Development

PROCEEDINGS

Edited by

Rob Koper and Krassen Stefanov

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Workshop "Learning Networks for Lifelong Competence Development"

Introduction

The first open workshop of the TENCompetence project took place in Sofia, Bulgaria, from 30th to 31st March 2006. These proceedings contain the papers presented in this workshop and accepted for the publication from the International Program Committee. In this introduction we initiate you to the TENCompetence project, the objectives of the workshop, and the papers that are included in the proceedings.

The TENCompetence project

The EU 6th Framework Integrated Project TENCompetence aims to develop an European, open-source infrastructure that will support the lifelong development of competences. The infrastructure will enable individuals, teams and organisations to:

1. Create formal and informal Learning Networks in different professions and domains of knowledge.
2. Assess and manage the competences that are acquired at any stage in life by the participants of the Learning Network, taking into account that people have learned from many different formals and informal learning sources.
3. Stimulate the reflection on the current competences to support the formulation of new learning goals.
4. Search for adequate formal and informal learning resources to build new competences or to update existing competences in a profession or domain of knowledge.
5. Provide the actual learning environment that is needed to perform the learning activities.
6. Provide effective and efficient support to learners.
7. Support the sharing of learning resources.

To this end TENCompetence is conducting RTD activities to further develop and integrate models and tools in four specific areas for the creation, storage and exchange of:

- knowledge resources,
- learning activities and units of learning,
- competence development programmes, and
- networks for lifelong competence development

The consortium, that consists of 13 partners from 9 countries, will conduct various large scale pilots; it will disseminate its products widely and for free; it will develop new business models for companies active in publishing, training provision, education, Human Resources Management (HRM) and technology support; it will train associated partners, and especially SMEs, to deliver these services.

The TENCompetence infrastructure can provide a tremendous push towards further integration and collaboration in support of the European knowledge society. It can be used at all levels of learning: primary, secondary and tertiary education; continuing education, adult and company training and all forms of informal learning.

The objective of the workshop

The objective of the workshop was to identify and analyse current research and technologies in the fields that provide the building blocks for the development of an open source infrastructure that contains all the services needed to support individuals, teams and organisations to (further) develop their competences, using all the distributed knowledge resources, learning activities, units of learning and learning routes/programmes that are available online. This includes open, usable and accessible services for:

- The creation, sharing, discovery and use of knowledge resources, learning activities and learning paths by any individual, team or organisation.
- The development, use, monitoring and maintenance of competence frameworks for the different professions or domains of knowledge.
- The assessment of competences.
- The registration, use and sharing of personal data (profiles, portfolios, certificates).
- The discovery of suitable learning resources adapted to the users needs and profile.
- The support of users to navigate through all the possible learning resources to build specific competences.
- The support for users to learn in new fields and the support for the people who provide the support (e.g. by providing monitoring services, help by email handling).

The papers

The papers were all reviewed by three reviewers from the programme committee. The best papers were also invited to deliver an elaborated version of the paper for a special issue of the journal Interactive Learning Environments (planned for 2007) on this same topic.

When we organise the papers of these proceedings into the categories of research we are performing in the TENCompetence project, we get the following organisation:

1. Knowledge resource sharing & management
- A note on organizational learning and knowledge sharing in the context of communities of practice
- Knowledge Resources Management and Sharing in the TENCompetence Project
- Selection and use of domain ontologies in Learning Networks for Lifelong Competence Development
- Learning Design Repositories – Structure Ontology and Processes
- PlanetDR, a scalable architecture for federated repositories supporting IMS Learning Design
- The OpenDock project: putting in place the infrastructure for sharing learning activities

2. Learning activities and units of learning
- Using IMS Learning Design to Model Curricula
- Integrating IMS Learning Design and IMS Question and Test Interoperability using CopperCore Service Integration
- The 8 Learning Events Model: a Pedagogic Conceptual Tool Supporting Diversification of Learning Methods
- Representing adaptive eLearning strategies in IMS Learning Design
- Seamless production of interoperable e-Learning units: stakes and pitfalls
- From collaborative virtual research environment SOA to teaching and learning environment SOA
- Learning Design Tool Implementation in ATutor

3. Competence development programmes
- Positioning of Learners in Learning Networks with Content Analysis, Metadata and Ontologies
- Navigational support in lifelong learning: enhancing effectiveness through indirect social navigation
- European Lifelong Competence Development: Requirements and Technologies for its Realisation

4. Networks for lifelong competence development
- Matchmaking in Learning Networks: A System to Support Knowledge Sharing
- Sharing personal knowlege over the Semantic Web
- Campus Canada Records of Learning: Secure validation of competence assertions
- Frameworks of competence: common or specific?
- Enhancing Social Navigation and Knowledge Exchange within Lifelong Competence Development and Management Systems: A Proposal of Methods and Tools

Although some sections have more papers than others, this will provide an adequate first input to all categories of work.

In conclusion

We think that the papers in this proceedings provide a valuable input for the TENCompetence project: they are a good representation of (parts of) the state-of-the-art in the fields related to lifelong competence development. We are just at the beginning of our challenging process and we see this as a valuable result of our first open meeting.
As chairs of the programme committee and editors of these proceedings we want to thank everybody involved in the process, especially the members of the local organisation committee from the Sofia University "St. Kliment Ohridski", the authors and presenters and the members of the programme committee.

The editors:
Rob Koper
Krassen Stefanov

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A note on organizational learning and knowledge sharing in the context of communities of practice*

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Abstract: The knowledge management (KM) literature emphasizes the impact of human factors for successful implementation of KM within the organization. Isolated initiatives for promoting learning organization and team collaboration, without taking consideration of the knowledge sharing limitations and constraints can defeat further development of KM culture. As an effective instrument for knowledge sharing, communities of practice (CoP) are appearing to overcome these constraints and to foster human collaboration.

Keywords: knowledge sharing, learning organization, communities of practice, knowledge management

1. Introduction

During the emergence of the Knowledge management (KM) theory, the initial focus was mainly on technologies, information tools, KM methodologies and roadmaps. The main emphasis has now shifted to human factors, or human-centered KM, as it was realized that human beings are the primary source of tacit knowledge in organizations. Presently, the third generation of KM is in place according to the classification cited in [5], and the focus is put on people as unique holders of knowledge, and the exchanges between people. The knowledge networks and working groups are considered as support for collaboration, and ideas, people and projects are primary generators of new knowledge and innovations.

The main goal of this article is to summarize some of the recent views about knowledge management as an enabler of learning organization, prioritizing the human aspects, and putting the focus on knowledge sharing and knowledge dissemination practices. In order to provide a deep understanding of the emergent practices, the characteristics of communities of practice (CoP) will be discussed in more details.

2. Organizational learning and knowledge sharing

The growing intensity and dynamism of competition has forced firms to focus their long-term strategies on resources and capabilities. Intellectual capital has emerged as one of the firm critical resources, and the ability to build and exploit intellectual capital has become their most strategically significant capability. Many theorists consider it as a combination of customer capital, organizational capital and human capital. Here, human capital serves as a collective term for an organization’s core competences, the skills and knowledge that the enterprise draws on to create and innovate in order to remain competitive. Therefore, any attempt to exploit intellectual capital for competitive advantage must be based on a sound understanding of an organization's current approach to acquiring, sharing and utilizing knowledge. As suggested in [11], knowledge management should begin with a focus on organizational learning, and by building and facilitating communities of practice.

2.1 Organizational learning

Organizational learning is a key dimension to KM, which involves a continuous assessment of organizational experience, including that of CoP, and converting that experience into knowledge and making it accessible to the organization as a whole. Two different kinds of organizational learning processes are identified: *learning how* (organizational members engaging in processes to transfer and improve existing skills or routines and learning) and *learning why* (organizational members diagnosing causality).

Organizational learning requires organizations to have "a shared memory" where individual employees' discoveries, inventions, and evaluations are embedded. Subsequently, under organizational or collective knowledge is understood knowledge in rules, procedures, strategies, activities, technologies, conditions, paradigms, or frames of references around which organizations are constructed and through which they operate [1].

Collective (team and organizational) learning requires skills for sharing information and knowledge, particularly implicit knowledge, assumptions and beliefs that are traditionally "beneath the surface". The main skills are: *communication* (especially across organizational boundaries), *listening and observing*, *mentoring and supporting colleagues*, *holistic perspective* (seeing the organization as a whole), *coping with challenge and uncertainty* [3]. Learning provides the opportunity to create and recreate, change one's external perception of the world and relationship with it, and extends individual ability to be creative. Further, there are two aspects to this: "adaptive learning," which is about survival; and "generative learning," which enhances one's ability to create [8].

Organizations, by their very nature as social systems, are the environments in which learning takes place. As such, the organization design plays a critical role in creating an environment that fosters knowledge creation and the development of human capital.

2.2 Knowledge Sharing

Knowledge management is not about managing technology alone, but is about managing how human beings can *share their knowledge* effectively [6]. The 'real' information system is built upon organizational culture and interpersonal communication and contains rich and dynamic tacit knowledge, which, if it is harnessed and managed effectively, can give organizations competitive advantage. Sharing expertise requires building a culture of trust, and any organizational practice or action that destroys trust adversely affects the motivation to share information with others [1].

At the heart of knowledge sharing lie two types of individuals: *knowledge seekers*—those who are looking for knowledge, and *knowledge sources*—those who either have the knowledge the seeker needs or who can point the seeker to another knowledge source. Effective knowledge sharing occurs when appropriate connections are built between these parties. However, there are four important barriers to knowledge sharing that CoP help to overcome [4]:

- *Awareness:* Making seekers and sources aware of their respective knowledge
- *Access:* Providing the time and space for seekers and sources to connect with one another
- *Application:* Ensuring that the knowledge seeker and source have a common content and understanding necessary to share their insights
- *Perception:* Creating an atmosphere where knowledge sharing behaviors between seekers and sources are respected and valued

Expertise sharing focuses on the human components – cognitive, social, cultural, and organizational aspects of knowledge work – in addition to information storage and retrieval. Compared to traditional approaches, which emphasize the role of management in organizing knowledge exchange, this perspective focuses on self-organized activities of the organizations' members. In enabling sharing, organizations try to connect people to one another so as to bolster communication, learning, and organizational knowledge. Expertise management includes communities of practice and knowledge communities, which attempt to increase communities', professions', and groups' overall expertise.

In [1] are considered the following three types of knowledge sharing within organizations:

- *Knowledge retrieval:* Knowledge sharing from the organization to the individual has the purpose of retrieving existing organizational knowledge.
- *Knowledge exchange:* Knowledge sharing from an individual to other individuals has the purpose of exchanging existing individual knowledge.
- *Knowledge creation:* Knowledge sharing among individuals has the purpose of generating new knowledge, resulting from new combinations of existing individual, shared, or organizational knowledge.

2.3 Barriers and limitations of knowledge sharing

Cultural factors are considered in [11] to essentially inhibit knowledge transfers. They include lack of trust, different cultures and vocabularies, lack of time and meeting places, lack of absorptive capacities in recipients, belief that knowledge is prerogative of particular groups, etc.

In [1] are considered deep-rooted cognitive and motivational limitations that interfere with people's ability to share and transfer their expertise:

- *Cognitive limitations* are related to the way experts store and process information, impeding them to share that expertise with others regardless of whether or not they are motivated to do so. The cognitive limitations faced by experts come partly from the way that they mentally represent the task, as expertise increases, mental representations become more abstract and simplified.

- *Motivational limitations* are related to the appraisal and reward systems of most companies, as well the internal competition between individuals, teams and units. Knowledge transfer requires resources of time and energy and the lack of company understanding and policy disturb the process as personnel need to be compensated for the invested time in knowledge sharing and conversations.

Motivational barriers to sharing expertise are more easily addressed through changes in organizational practices. The motivational issues can be addressed by reducing competition between groups, allowing communities of practice to evolve, deemphasizing status hierarchies, and increasing incentives to share expertise with others.

3. Communities of Practice

As successful example of sharing and transferring knowledge practice will be presented the Communities of Practice. The definition of a community of practice is "a group of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in an area by interacting on an ongoing basis" [10]. These groups tend to interact regularly by meeting face-to-face or relying on technology to facilitate discussion and due to theirs members' desire to exchange knowledge.

3.1. The CoP concept and attributes

Although the term "Community of Practice" is new, the CoPs are not. The concept of a community of practice is an extension or a variation of the concept of special interest groups, clubs, medieval guilds, and even regions for certain industries [3]. In [11], for example, is considered a 'community of knowers' brought together by a common interests, including people who exchange knowledge and expertise by face-to-face communications, on the telephone, via e-mail or groupware, in 'talk rooms', etc.

CoPs are described as differing from traditional team-working approaches in that they are most likely to be cross-functional and multi-skilled, where functional position is irrelevant and the topic knowledge or interest is all that is necessary to join a CoP [7]. The diversity of a CoP's population may encourage creativity and problem solving, and linkages to external communities will also enhance their activities, as CoPs are the legitimate place for learning through participation. They additionally provide an identity for the participator in terms of social position, knowledge attributes, and ownership.

Important for CoP attributes are [7]:

- *variety*—multi-skilling prevents boredom and monotony, and builds flexibility;
- *identity*—building an identity encourages a sense of collective responsibility and self-regulation of variances;
- *significance*—motivation to care about the outcome of the work process increases cooperation when the outcome is imbued with a sense of significance;
- *autonomy*—increases the ownership and responsibility of members to the process and also enables the group to make decisions under changing environmental conditions; the multi-skill also enables them to flex attributes and change working practices to fit with the environmental changes;
- *feedback*—understanding and knowing the results of work processes enables groups to monitor their progress against targets and improve their performance.

Finally, four main *types of communities* could be considered [9]:

- innovation communities
- helping communities
- best-practice communities - attaining, validating and disseminating knowledge;
- knowledge-stewarding - connecting people and collecting information and knowledge across the organisation.

All CoPs contain people undertaking *different roles* within them: community sponsor, leader, and members [2]. The sponsor is a person with vision, assisting in the set-up and maintenance of the community and providing not just moral support but also financial and public relations, while the leader is the person with the passion and expertise in the area, possessing a number of leadership and communication skills.

3.2. CoP characteristics derived from practice

Several different cases related to CoP building and managing are presented in [4]. The issue of viable CoP is discussed on bases of case study on experience with successful CoPs at Siemens AG. Trying to find out what creates and sustains viability in CoP, the authors introduce five factors for the viability of a CoP:

- *Organizing and Facilitating Community Activities*

The CoP provide knowledge to their members. The "management activities" needed for this to take place are to organize and facilitate CoP activities, both using face-to-face meetings, and a common IT-platform.

- *Connecting People and their Knowledge*

The coordination of the knowledge needs and haves of individuals and groups in the CoP takes place as people and their knowledge are connected. Even though all of the CoP members contribute to this task, the moderator plays a special role in facilitating this process.

- *Finding a Common Focus*

The third factor for a viable system is the overall optimization of activities. The content and extent of current activities are directed by the common focus of the CoP. Finding a common focus gives overall direction for the community - it is when the community decides on what they actually want to do and it determines meeting agendas or frequency of activity.

- *Interacting with the Community Environment*

CoPs that are embedded in an organizational context have an internal and an external organizational environment to monitor and interact with. They should consider also the corresponding future changes of this environment.

- *Living the Community Values*

Values and rules set the normative framework for a viable CoP. To them belong trust and openness, a balance between giving contributions and taking solutions from others. Some viable CoPs set explicit rules which can refer to the communication within the community or can affect the behavior of its members.

Finally, successful CoP should exhibit the following 10 characteristics [9]:

- a compelling, clear business value proposition;
- a dedicated skilled leader;

- a coherent, comprehensive knowledge map for the CoP's core content;
- an outlined, easy-to-follow knowledge sharing process;
- an appropriate technology medium that facilitates knowledge exchange, retrieval and collaboration;
- communication and training plans for those outside of the CoP;
- an updated, dynamic roster of CoP members;
- several key metrics of success to show business results;
- a recognition plan for participants;
- an agenda of topics to cover for the first months of existence.

4. Conclusions

The knowledge management theoretical and practical literature review emphasize on organizational learning and knowledge sharing as major factors for success of the KM initiatives within the organization. As the focus is put on human factors, the main limitations for effective collaboration are related to the human nature and lack of adequate motivation policy. In this context Communities of practice are appearing as an instrument, overcoming the behavior constraints and manifesting the emergence of new organizational culture.

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Knowledge Resources Management and Sharing in the TENCompetence Project

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***Abstract*: One of the most relevant activities in the EU TENCompetence project is directed at the development of models and tools to stimulate the sharing and management of knowledge resources. Knowledge resources are the containers that store the explicit knowledge for sharing purposes. Examples are learning objects, articles, books, software programs, informal messages, etc. From the technical perspective the main outcome of this part of the research in TENCompetence is to develop an infrastructure suitable to provide users with functionalities for the creation, storage in distributed, federated digital repositories, search, support, retrieval, packaging, reuse, sharing and quality rating of knowledge resources. Moreover, in order to guarantee a high degree of interoperability, each knowledge resource must be both packaged according to existing specifications (e.g. IMS-CP and SCORM) and uniquely identifiable using worldwide unique identifiers and metadata descriptors (e.g. LOM or Dublin Core format). This paper is an overview on the objectives, issues and potential technical solutions identified in the initial phase of the project.**

***Keywords*: Content management, knowledge management, knowledge modeling, knowledge sharing.**

I. Introduction

From a general perspective, not necessarily related to a learning process, some of the specific business and organizational factors justifying KM adoption include the need for increasing competitiveness and rising the innovation rate [1]. Furthermore, more and more informal knowledge has to be replaced with formal methods, this in order to deal with increasing competitive pressure by reducing the amount of people that holds valuable knowledge and limiting the effects of a loss of knowledge due to early retirements and increasing mobility of workers.

Another aspect that has to be considered is the possible loss of knowledge in specific areas due to quick changes, which are normal in the modern society as well as in market's strategic directions. This, combined with a limited time availability for experiencing and acquiring new knowledge, is rising a need for solutions suitable to manage increasing complexity.

Besides the previous considerations it is worth noting that most of human activities, as well as many aspects affecting normal life, are heavily information and knowledge-consuming. For instance, organizations compete on the basis of knowledge, products and services are increasingly complex and endowed with a significant information component. This means that life-long learning is more and more an inescapable real and urgent need.

It can be said then that knowledge and information domains have become a relevant space in which problems occur, from everyday life issues to learning/training and business processes. As a result, managing and appropriately sharing knowledge represents the primary opportunity for achieving substantial savings, significant improvements in human performance, and competitive advantage.

Within this context the TENCompetence project aims at investigating aspects of knowledge resources management and sharing (KRMS) from the perspective of learning processes and scenarios. The final objective is to develop an infrastructure for managing and sharing whatever kind of knowledge resources and suitably support innovative knowledge exchange paradigms and models within learning activities. This will be achieved through some consistent and correlated tasks.

As a first step liaisons with other initiatives in the KRMS area are needed to both avoiding reinventing the wheel and promoting the adoption of open standards and protocols. Furthermore, components should access and use existing libraries of knowledge resources were possible.

The following step is the selection and adaptation of existing tools is considered, to create a set of KRMS components that can be integrated as services within an integrated complex system that will be evaluated and in terms of efficiency, effectiveness and usability.

Outcomes from the assessment activity will allow defining a roadmap for further research and development in the field of KRMS.

With respect to these objectives and activities, the following sections are devoted to a description of the main issues that need to be dealt with and a preliminary proposal for a conceptual and technological framework that could be adopted in TENCompetence for providing KRMS features.

II. What is Knowledge Resources Management?

When dealing with knowledge management the first issue is to define the concept of *knowledge* itself, as this definition will directly impact the whole discussion eventually even preventing a real in-depth understanding on what exposed. Therefore, as usual in any multidisciplinary environment like TENCompetence, it is necessary to agree on used terms in order to fully avoid misleading assumptions.

Unfortunately, there's no universal definition of knowledge management, just as there is no agreement as to what constitutes knowledge in the first place [2]. Over the millennia, philosophers and scientists of each age have added their own definition of knowledge to the list. For instance according to Plato, as emerging from his *Dialogues*, and other ancient Greek philosophers we could say that:

- knowledge is what is true. What is true represents reality as it is and therefore *knowledge represents reality as it is* (Socrates)
- conceptual knowledge is truly knowledge for us (psychological fact), so *conceptual knowledge represents reality as it is*
- conceptual knowledge represents reality as static, eternal and necessary. (Parmenides)
- the phenomenal world (*becoming*) is not static, eternal and necessary. (Heraclites)
- the phenomenal world is not reality. Therefore *conceptual knowledge doesn't represent the phenomenal world*.

From what just stated is apparent that the concept of knowledge can be split in *what is absolutely true* (maybe also unknowable) and *what is perceivable*. In the latter, knowledge is specific to the cognitive system that created it, not residing outside the cognitive system.

Moving from the pure concept of knowledge to a reasonable and applicable definition of knowledge management, also in this case several attempts have been made and can be found in the related literature. Starting from this and taking into account the specific objectives and constraints in the TENCompetence project with respect to knowledge resources management and sharing features, we could say that the main high-level requirement for the KRMS components is to contribute to the logical and practical flow that goes *from basic knowledge resources to complex learning activities* support.

The basic assumption behind such a requirement is that any piece of knowledge, whatever it is from e.g. a simple image up to a complex learning path, can be looked at as a self-consistent object with common rules for storage, retrieval, indexing, etc. at least with respect to low-level management and sharing. This doesn't mean that the KRMS will provide features as, e.g., a units of learning editor, as these will be offered by upper layers in the TENCompetence system. On the other hand, at the infrastructural level a unit of learning will be looked at as a knowledge resource.

To fulfill such a macro-requirement it is necessary to supply a complete and consistent infrastructure suitable to be used for managing and sharing any kind of information produced and exchanged within the integrated TENCompetence system.

Actually this top-level goal implies two different sub-objectives, which will be deepened afterwards:

- on the *methodological side*, defining innovative models and approaches for stimulating the active creation and sharing of knowledge resources
- on the *technical side*, providing knowledge resources storage, retrieval, rating and many other related functionalities, throughout a federated set of repositories, for any relevant piece of knowledge (knowledge object) processed and exchanged within the system (basic knowledge resources, units of learning, learning activities, learning paths, etc.).

III. Categories of Knowledge Resources

This section aims at offering some insight into the different categories of knowledge resources that the KRMS subsystem should be able to manage. Two main categories can be identified: *material* and *immaterial*.

A. Material knowledge resources

In this category the most traditional kinds of multimedia resources can be listed, like e.g. text and hypertext, images, 2D/3D graphics, audio files, videos and animations.

Additionally, also some more heterogeneous objects can be collected under the category of material knowledge resources. Some examples are: planning and design documents, resources descriptors and references, executable programmes and libraries, source code and scripting languages.

Furthermore, specifically for e-learning in general and for TENCompetence in particular, as already highlighted previously we shall also consider the following:

- metadata and related vocabularies
- learning objects
- units of learning
- learning activities
- learning paths
- learning networks

Archiving formats have not been considered on purpose since the related compression tools do not alter the properties of the processed resources.

B. Immaterial knowledge resources

Within this category some resources can be grouped that are normally underestimated and will require a specific effort to be properly modeled:

- human resources (i.e. a projection of personal skills, acquired competencies, personal abilities, natural capabilities, personal field expertise)
- Human Area Network (HAN) resources, i.e. communities of connected human beings and mobile terminals and devices (e.g. RedTacton)
- "environmental" resources (e.g. organizational know-how, training and lifelong learning policies at

European/National/local level).

In the next paragraph some considerations on human resources are provided in order to better focus on the added value represented by their usually unexpressed potentialities in terms of effective '(re)sources' of knowledge.

C. People as knowledge resources

Most of the existing Knowledge Management Systems (KMSs) apply the traditional document-centered methodology for managing knowledge. Such classic approaches have some advantages, such as providing users with a powerful means to access and manipulate a huge amount of *formalized* and *formalizable* domain-dependent knowledge [3]. On the other hand, they also show some major limitations.

In general *tacit* and *implicit knowledge* (i.e. knowledge that is not available in existing documents but mainly present in people's heads) are not taken sufficiently into account [4], [5]. Moreover, the delivered knowledge is static, frequently not properly represented, often obsolete, incomplete and disconnected from the specific context of use. Finally, both supplied knowledge and delivery mode normally are not contextualized and do not take into account current activity, existing user's competencies and working/learning style [6], [7].

These limitations are particularly frustrating in the context of modern professional fields, which need to be flexible and adaptable and for which a large amount of knowledge (experiences, social knowledge, or know-how) is not formalized in repositories but is present in people's heads.. As a consequence, Knowledge Management Systems have to be defined to support these new settings and in particular, the knowledge-related activities of knowledge workers which have considerably evolved in this last decade. To this end in TENCompetence the design of the KRMS functionalities will consider at least two fundamental factors: the *users (learners)* - with their targets, intentions, attitudes (e.g. towards competency development and/or using a CMS), motivation, etc. – and the *social network*, which provides the context in which competency development takes place and encompasses many different types of relationships users have and develop with other individuals both in specific communities as well as in broader social contexts.

From this perspective, the KRMS subsystem will rely on a new vision that requires a fundamental shift from current content-oriented e-learning solutions towards a more user-centered, interactive and collaborative model of learning. In the new model, the learner is no longer considered as a simple passive recipient of data and information, but is seen as a participant that is actively engaged through a rich set of interactions (e.g. learning by doing, educational games, simulation environments, problem-based learning, learning by discussing, knowledge discovery, etc) [2], [9].

This set of processes plays an important role not only for the delivery of the knowledge, but also in the knowledge selection process, the stimulation of the learner, the construction and the internalization of this knowledge, the validation of this knowledge, its situating in a social context, and its application in real world situations.

Within the context of the TENCompetence project, extending the concept of knowledge resource to people is a key research objective, which has been addressed from the very beginning but will require thoughtful analysis and, in the medium/long term the design of suitable and innovative knowledge resources management models. Results from this process will be presented in future publications.

IV. Proposal for a Technological Framework

A proposal for a technological framework suitable to support knowledge resources management and sharing according to the previously discussed requirements, criteria and constraints has been drafted, for further discussion and refinement.

Ideally, the functionalities identified during the design phase can be collected under a so-called *KRMS Component*. This will be smoothly integrated into the TENCompetence infrastructure in order to provide other modules and services in the system with functionalities for creating, processing, indexing, publishing, retrieving and properly sharing any typology of knowledge resources.

A direct consequence of such a definition is that in other to give support to specific searches some semantic has to be associated to each different kind of knowledge object: basic knowledge resources (KR), units of learning (UoL), learning activities (LA), learning paths (LP), etc. This can be achieved by allowing at each level users of the KRMS Component to provide proper metadata they consider as relevant (see Figure 1).

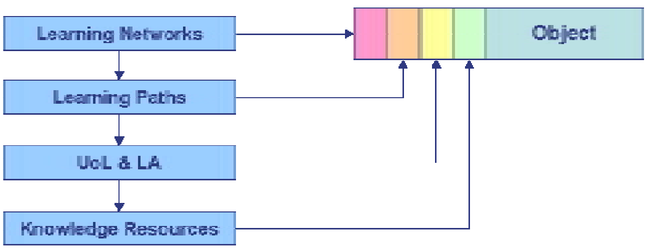

Figure 1: Structure of a knowledge object.

Internally the KRMS Component will be based on a *service-oriented architecture* or *framework,* conceived and designed in order to efficiently support the requested features. Some basic services in this framework have been already identified and need further specification effort:

- *Knowledge Resources Management Service*
- *Knowledge Resources Creation Service*
- *Knowledge Resources Packaging Service*
- *Knowledge Resources Indexing Service*
- *Knowledge Resources Annotation Service*
- *Knowledge Resources Tracking Service*
- *Knowledge Resources Rating Service*

- *Knowledge Resources Personalization Service*
- *Knowledge Resources Customization Service*
- *Knowledge Resources Search Service*
- *Digital Repository Management Service*
- *Workflow Management Service*
- *Metadata Exchange Protocol Service*
- *Taxonomy Management Service*
- *Ontology Management Service*

In other words, also following the project philosophy of using available open source for the implementation, the idea is to design an abstract architecture for the KRMS Component and then to match as far as possible the identified services to already existing components.

The KRMS Component and its functionalities will be then accessed by external service consumers (e.g. users through the *TENCompetence Client*, the *UoL&LA Component*, etc.) through a limited number of well specified and described interfaces. Figure 2 represents the dependencies amongst a sub-set of the KRMS services (in blue) and the communication with the TENCompetence Client (in yellow).

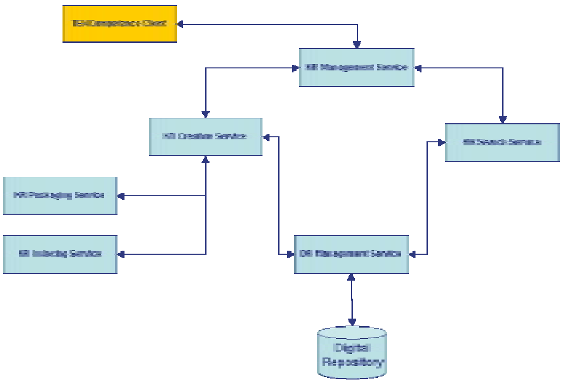

Figure 2: A view on the KRMS Component.

To get a high level of flexibility and extensibility, at the infrastructural level the KRMS Component will refer to three basic assumptions:

- the services provided by the KRMS Component will sit on top of an extended federation of CMSs and KMSs, i.e. a large, reconfigurable, open and interoperable network of heterogeneous content and knowledge management systems
- the architecture for knowledge resource sharing will be based on a peer-to-peer (P2P) network. The clients of this network could be any kind of existing digital repositories, content and knowledge management systems.
- every client will be connected to the P2P network by means of open, standardized and *abstract* interfaces. This will allow the integration of new heterogeneous clients within the federation by simply implementing a specialized version of these interfaces.

Innovative P2P applications and services are enabling interactive communication with almost any device on the expanded Internet, thus helping the delivery of the right information and services anywhere on the network and providing better access to network resources while maintaining uncompromised security. For instance, if a P2P configuration is considered with a central index server, this does not contain files physically and only maintains the information about users who are logged on to the network, the IP address of the client and the list of files shared at any given moment by a user.

A proposal for a P2P-based technological framework suitable to support knowledge resources management and sharing has been drafted, for further discussion and refinement. This would be based on two existing infrastructures: LionShare [10] and the OKI-OSIDS [11].

The LionShare P2P project is an effort to facilitate robust and secure file-sharing among individuals and educational institutions around the world. In the role of provider, LionShare offers an implementation of the OSID Digital Repository (OSID-DR) interface that provides access to resources on their Peer-to-Peer (P2P) server network. This allows many applications accessing knowledge resources on the server network for no additional development effort beyond the initial adoption of the OSID specification.

In the role of consumer, LionShare's desktop client application can include any OSID-DR implementation as part of a federated search. In other words, by embracing the OSID specification applications gain access to more resources and knowledge resources providers (either knowledge management systems, which can manage advanced search functionalities and also optionally share knowledge resources, or generic digital repositories that can only share resources) could address a wider market at a low marginal cost.

V. Conclusions

One of the most challenging objectives in the TENCompetence project is the design and development of an innovative knowledge resources management and sharing infrastructure. The paper provides an overview of the issues that need to be dealt with and also offers a preliminary proposal for a technological framework able to support innovative - more user-centered - models for promoting the use, creation and sharing of knowledge.

Next steps will be aiming at both the detailed specification of the described architecture and the definition of a robust approach for capturing and representing domain-dependent knowledge spaces. The latter point will be very relevant, as without a model of the knowledge space corresponding to a specific application domain it is very difficult to support effective and efficient learning processes in that domain. This means trying to understand which kind of knowledge resources are relevant for a specific learning domain (e.g. videos for digital cinema vs. text in literature), what criteria need to be applied for sharing, which are the major knowledge sources in that domain, etc.

These aspects, as many others in the paper, will require further in-depth research. Considering also that the TENCompetence project is at its early stages, more achievements and results will be presented and discussed in future publications.

ACKNOWLEDGMENTS

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Selection and use of domain ontologies in Learning Networks for Lifelong Competence Development

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A general problem in life-long learning is how to develop flexible and adaptive learning content, and how to choose and deliver the most appropriate learning activities for the learner. In order to solve this problem, we need to have the proper knowledge model, and clear interpretation how to use it. One possible solution is to use IMS Learning Design for modelling the learning process and ontologies for representing the domain knowledge and competencies. In this paper we present one specific approach for applying this solution, and one possible implementation of this approach. We also analyse possible technological tools to be used in such implementation, and give reasons for our choice. We describe the current results from this implementation, and outline the problems encountered, as well as the research challenges remaining to be solved.

Keywords: ontology, learning design, semantic Web, production rules, Protege, RuleML.

Introduction

In this paper we analyse how and why domain ontologies can be used in Learning Networks for Lifelong Competence Development (LN4LCD), and discuss the problem of reusing domain ontologies in different LN4LCD. Then we present an approach to solving this problem and give a scenario for experiments. We provide a comparison of ontology description languages and tools and select the language and tool that best match our needs. We discuss some current solutions and results and propose specific actions and ideas of how to proceed further.

1. Analysis of the knowledge frameworks for LN4LCD

A general problem in life-long learning is how to develop flexible and adaptive learning content, and how to choose and deliver the most appropriate learning activities for the learner. This problem is related to identifying and representing the learner's current knowledge and the competence level s/he wants to achieve, and using those to formulate a personal competence development plan for the learner.
There are several approaches for representing such types of knowledge [9, 11, 12, 20, 21], but two are gaining recently more importance: using standards (like the full set of IMS e-learning specifications) and applying ontologies and Semantic Web technologies for description and classification of the subject domain.

Ontologies are mostly used for modelling the domain knowledge. They can be used for modelling both learner's knowledge and different competence levels related to the domain. In addition to these two models, a suitable mapping engine is needed to compare them and generate a personal competence development plan for the learner, which can help him to achieve a specified competence level.

IMS Learning Design (IMS LD, [22]) is a standard, allowing instructional knowledge to be represented by using the concepts of Unit of Learning and Learning Activity. As it is outlined in [20, 21] among others, the combination of ontologies and IMS LD could bring enough power for modelling the knowledge in the LN4LCD, allowing enough flexibility and adaptability in the learning process. We also adopt this approach for knowledge modelling, and use IMS LD for modelling the learning process and ontologies for representing the domain knowledge and competencies.

Since flexibility is an important issue, our ontology has to be easy re-usable from different Learning Designs. In order to allow the generation of learning paths, the ontology needs to have mapping capabilities (to allow easy mapping between two knowledge representations).

2. Our Approach

In our approach the units of learning are indexed through IMS compliant metadata. The information about the relations and interdependency between the units of learning is formalized through the domain ontology, allowing the design of abstract and simplified views of training domains.

Each unit of learning can be linked to some concepts and relations from the domain ontology - the ones, which can be learnt at some level of proficiency by using that unit. This link is naturally represented by the metadata description of the corresponding unit of learning.

The learner's current knowledge (personal competencies) will be identified from his personal portfolio, personal information available, or through using some standard assessment techniques like tests. As a result, a student model will be created.

Thus for each competence level the learner wants to achieve, we can automatically map these two models and derive a competence development plan (learning path), expressed by a specific set of learning activities, using a specific set of units of learning. More than one possible learning path will be typically created for a learner. Those paths can be further analysed depending on different parameters (time needed, cost, quality, difficulty, etc.), and the best suitable learning path for the learner could be chosen.

We plan to experiment with our approach as part of the activities in the TENCompetence project [23]. We will use a prototype of the Computing Ontology [18], developed in the frame of the DIOGENE project [19], and two or three different learning designs, corresponding to different models of learning.

The Computing Ontology prototype is based on the SHOE formalism [8], and created in the Protégé editor [10]. The main problem with the prototype is that the reasoning part of the ontology is hidden in the DIOGENE system, and as a result is not reusable. Another problem is related to the existing relations, which actually contain not only domain knowledge, but also instructional knowledge. So, we need to re-design the existing ontology, separating the domain knowledge from the instructional knowledge, leaving the instructional knowledge as part of the learning design. In order to make the ontology reusable in different settings, we need to use an implementation tool, which combines the language representation power with the suitable inference engine, that can use not only the domain knowledge, but also the pedagogical knowledge expressed in the LD specifications.

Our next task is to choose the right tool for the ontology implementation.

3. Comparison of ontology description languages and criteria for selection of the most appropriate one

An ontology is usually composed of: classes of objects, a vocabulary of terms (instances), and various relations between classes or terms and classes. A critical step in ontology development is the selection of the most appropriate language for ontology description, and tool for performing the basic ontology operations.

Ontology languages can be divided in two major groups: traditional and web-based languages [1, 3]. Some traditional languages are Flogic, OCML and Ontolingua [17]. Other ontology languages like XOL [7], OIL [6], SHOE [8] are defined as web- based languages. On the other hand, we have languages, used mainly to physically code some ontology formalism, which are named representation languages. The most widespread such languages are XML [4], UML, RDF.

Other languages like PIF and KIF [5] are used mainly for conversion between different ontology languages, supporting the process of interchange between different ontology formalisms.

We will extend this classification with new type of languages: rule-based, like RuleML [2] and WRL [13].

Of course, some languages can be included in more than one group. Some of the traditional languages have been extended with additional, flexible and interactively updated information, making them very close to Web-based languages, like OWL [15]. Some other languages combine characteristics of web-based and rule-based languages, as SWRL [14].

The extended classification of all types of ontology description languages, as explained above, is shown on Fig.1

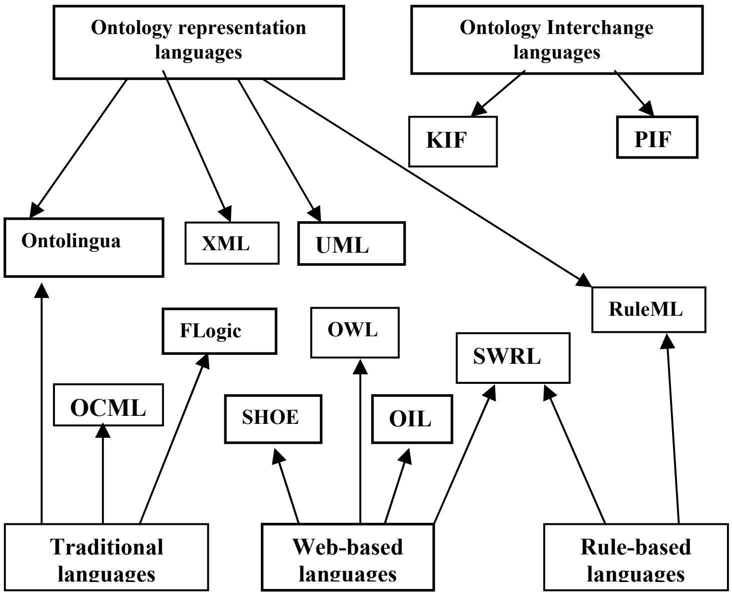

Fig.1 Ontology languages classifications

On the base of this classification, we analyse the most widespread ontology languages, using two main groups of criteria.

The first group (linked with the re-usability of the ontology model) organizes components of ontology like capabilities of language to describe ontology concepts, axioms, taxonomies and production rules.

The second group contains characteristics related to tools for ontology creation, validation, effective use and further development. It is related to the re-usability of the ontology operations.

Using different sources, including [24], we have collected and summarized the needed information in Table 1.

Characteristics	Traditional languages				Web-based languages			Rule-based language		
	Ontolingua	OCML	FLogic	LOOM	SHOE	OIL	OWL	RuleML	WRL	SWRL
Concepts	+	+	+	+	+	+	+	+	+	+
Taxonomy	+	+	+	+	-	-		+	/	/
Relations	+	-	-	-	+	+		+	+	+
Functions	+	/	+	-	-	+		/	-	+
Axioms	+	-	+	+	+	/	+	+	+	+
Instances	+	+	+	+	+	/	+	+	+	+
Production rules	-	+	-	+	-	/	+	+	+	+
Queries	-	-	+	/	+	-	/	+	+	+
Translators	-	/	/	+	+	+	+	+	/	/
Engines	/	-	+	-	-	/	/	/	+	+
Editors	+	+	-	+	+	+	+	/	+	+
User Interfaces	+	+	/	+	+	+	+	+	+	+

Table 1 Ontology languages comparison

Sign "+" is used to represent the availability of a feature, sign "-" to represent a missing feature, and "/" is used to show missing or not definite information about a required characteristic.

On the base of analysis of the data presented in Table 1, it is clear that only rule-based languages are useful in our case, because only they guarantee re-usable ontology operations. Having in mind the syntax and tool used to define the prototype, SWRL seems to be the best choice, as (1) it is supported by the Protégé editor; (2) being based on OWL, it will be easier to convert and reuse different types of ontologies; (3) it is in very close relation and conformance with the RuleML initiative.

4. Implementation of ontologies in LD4LCD

Our next goal was to redesign the Computing ontology prototype using the Protégé editor and the SWRL language. We did this transformation using the Protégé features and made the transformation in two steps: first we transformed the ontology from SHOE to OWL, and then from OWL to SWRL.

Protégé can be used to develop rules for reasoning that allow providing of more effective and efficient support for life–long learning. (Fig. 2)

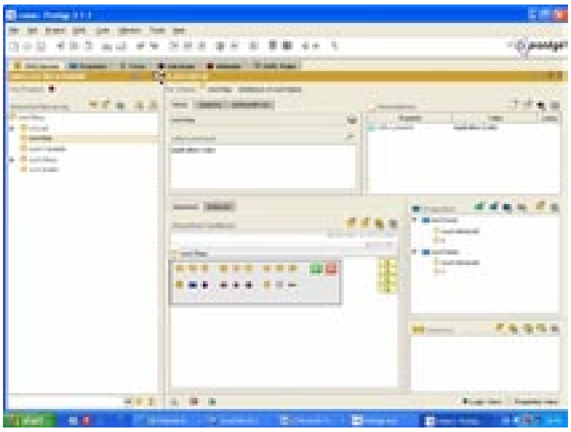

Fig. 2 Protege-OWL as a tool for editing of rule bases in SWRL

Algernon Protégé plug-in provides capabilities for rules manipulation as it is shown on Fig 3.

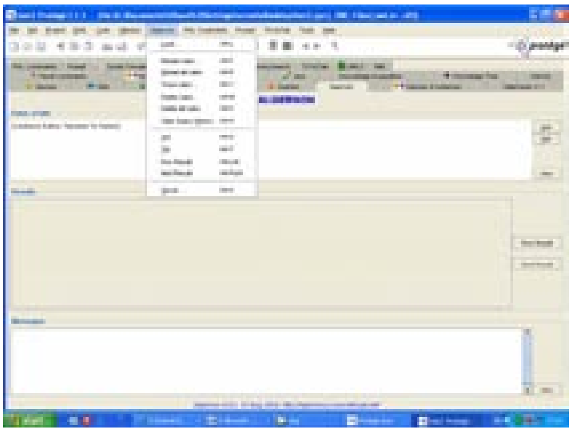

Fig. 3 Rules manipulation capabilities

Our new ontology has the possibilities for describing and using markup harmonization, rule syntaxes, rule modules and rule application. It extends rule expressiveness and rule semantics, and allows using RDF rules, ontology mapping and ontology coupling, rule validation and rule compilation. Other important features include using the capabilities for XML stylesheets, semiformal rules and rule documents.

The most important advantage is the ability to separate the knowledge and reasoning about a specific learning domain in one single tool, to make this independent of the learning design description, logic and use, and in this way to allow real interoperability and reuse of both the learning design and the learning domain ontology.

After we implemented the Ontology, our next steps are: (1) to combine the existing knowledge from the domain ontology, with the information and knowledge embedded in the learning design; (2) to formalise the mapping between the learner's model and competence model; (3) to generate different learning paths corresponding to the mapping of the models; and (4) to implement an algorithm for choosing the best learning path.

5. Conclusion

In this paper we presented an approach for using learning domain ontologies in LN4LCD. We discussed the problems with the reuse of such an ontology in different settings and different LN4LCD. On the base of one existing domain ontology, we chose the best ontology language and tool for using it in these different settings, and successfully transformed the ontology.

The main advantage for dynamic learning is reducing the amount of proposed learning content in the generated learning path, since it is created on the base of a learner profile and adaptive learning material delivery.

The IMS LD specification is proposed to assure interoperability of learning materials and processes related to knowledge management within different learning domains.

Our future work is related to research and development of the capabilities of the relational ontology languages and their implementation in domain ontology description, in order to achieve better reasoning and classification expression power with regard to knowledge management and sharing, and in particular the best possible coexistence of such tools with standard tools supporting IMS LD specification, in a common framework – LN4LCD.

We also formulated several practical experiments, which can be further investigated in the framework of the TENCompetence project [23].

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Learning Design Repositories – Structure Ontology and Processes

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Abstract

We summarize here the results of a project called IDLD: Implementation and Deployment of the Learning Design specification. The main product of the IDLD project is a portal that provides a suite of tools and methodological aids to help build IMS-LD compliant learning designs. In this paper, we focus on a practical approach to build and extend a repository of learning designs. We present a more specific process where tools in the portal serve to extend the repository by building LD patterns extracted from an actual course, recomposing them into new patterns and new courses. We present a LOM-based LD classification scheme to help structure the repository. Finally, we present part of an ontology to improve the structure, and hopefully the usefulness, of the LD repository.

Key Words

Learning Design, Learning Object Repositories, Learning Design Methodology, Instructional Design, Learning Standards.

1. Results from the IDLD project

The deployment processes of a new technology or a new methodology are crucial for R&D results to reach users as innovative products and services that can produce quality and growth. These preoccupations are at the origin of the IDLD project, a continuation of our work in the R2R project [12]. The main results of the project are grouped is the IDLD Resource Center, a Web portal now in operation at www.idld.org providing access to a repository of learning designs, a suite of tools to support the deployment of IMS-LD, methodological aids to help in its implementation and a number of background documents and related sites.

The LD repository

Building LD repositories has been identified as a priority in a Valkenburg Group round table held in January 2004 [11].

The central resource of the portal is the LD repository. It contains actually a limited number of entries but it gives access to different kinds of products of the learning design implementation process: initial narratives of learning scenarios, graphic models of learning designs, IMS-LD compliant XML manifests and some learning designs embedded in complete on-line courses. The graphical models and their corresponding XML manifests are either LD examples, where the content resources are specified as items, or LD patterns that are design flows without specific content.

We believe that LD patterns are more interesting that other types of learning objects because they are ready-to-adapt multi-actor processes embedding learning and teaching strategies that can be reused in different knowledge domains. When a critical mass of LD patterns will be made accessible, we can expect a greater use of such repositories than content-specific ones.

Methodological aids to IMS-LD

Besides basic IMS-LD documentation, the IDLD portal offers a set of new methodological aids to instructional designers and educators involved in the implementation and deployment of IMS-LD

- A methodological guide to support IMS-LD authoring, validation and execution using the above tools or other alternative tools;

- A description of the classes of learning designs in the classifications we have used to provide metadata descriptors for learning designs;
- A set of best practices in the development and use of the learning design repository based on our experience in the project;
- A workflow model to help build units of learning or courses compliant with the IMS-LD specification.

A Suite of LD Tools

To support the development and use of the LD repository, the IDLD portal presently offers four tools:

- the MOT+LD graphic editor [10] that supports an interactive design process more friendly to designers than form-based editors, but limited to level A of the IMS-LD specification;
- the RELOAD editor [14] supporting A, B and C levels, but in a hierarchical form-based format;
- the RELOAD player, embedding the COPPERCORE [5] engine, that reads IMS-LD manifests and offers a Web-based interface to deliver and execute a LD run;
- PALOMA, a learning object repository management system (extracted from the Explor@ system [13]) that supports the IEEE-LOM and the IMS-DRI specification for federated search into multiple repositories.

These tools are sufficient to support the implementation process presented below; however, some limitations appear and we aim to extend this tool set with other open source tools that are being developed by us or other groups, particularly by partners of the LORNET research network (www.lornet.org).

In section 2, we will present how we have used the IEEE-LOM to structure the LD repository, in particular adding two classifications schemes into the PALOMA tool. In section 3, we will present a process for decomposing a course LD into smaller patterns and recomposing some of them into new courses. In section 4, we will propose an ontology to extend the LOM for structuring the repository and making more meaningful queries.

2. Classification of learning designs

To facilitate search in learning object repositories containing learning design products we needed to classify the LDs according to their main properties.

Figure 1 shows such a classification embedded in the PALOMA learning object manager. The left part presents a list of available repositories, including the IDLD repository; the center part shows a list of designs grouped in one repository; the right part is the section to creating, modify and view a standard IEEE-LOM record for the selected object. Here, this object is a learning design for a collaborative LD pattern entitled “FORUM SYNTHÈSE”.

For this LD, the user has selected metadata from the learning design classification: the delivery model is “Asynchronous Online Training”, the pedagogical strategy is “Debate/Discussion”, and the evaluation model is “summative”, based on “learner productions” that are “mostly individual”. These three top level categories of the learning design classification are extracted directly from the MISA method, an extensive work on instructional design methodology started in 1992, based on educational theories and knowledge/software engineering [2,8,9].

Category A400 of the classification specify a level of reusability of a learning design on different aspects, extending [1]. Since the LD here is a pattern, it is considered to be “technology independent”, “content generic”, “context-of-use independent” and “adaptable to certain disabilities”. Finally, category A500 describes the type of LD product, in this case an IMS-LD Graphical Model.

In the list of classification descriptors on figure 1, we see that the last entry shows metadata from another classification scheme on cognitive skills and strategies, also extracted from our work on MISA [7,10] and integrated in section 9 of the LOM. For the example, this metadata indicates that the learners will use and develop synthesis skills. We have discussed elsewhere why such generic skills and strategies are fundamental to structure learning design strategies.

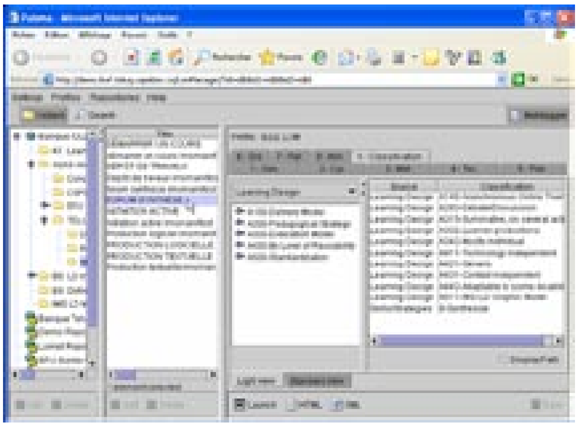

Figure 1 – Learning design classification and metadata association to learning designs

Other LOM entries are useful to provide some semantic structure to the set of LD products in a repository. We use the 1.8 section of the LOM to specify one of four aggregation levels:

1. Raw media (learning objects and services);
2. Lessons (grouping level 1 objects);
3. Courses (grouping level 2 objects);
4. Programs (grouping level 3 objects).

Section 7 of the LOM provides a limited set of choices for relations between learning objects LOM descriptions. We used some of them with the following semantics:

- "is basis for /is based on" indicates the relationship between a narrative or a textual course outline (or course plan) and a graphical model or an LD manifest ;
- "has format/is format of" indicates the relationship between a graphic model of a UoL, an IMS-LD manifest or an executable Web version of the same UoL;
- "has part/is part of" will indicate the relationship between a LD product and its components, for example, between a level 3 (course) and a level 2 (lesson) object.
- "has version /is version of" is re-interpreted as the relationship between a pattern and its examples obtained by associating precise items to the abstract objects (environment, activity, role,…) in a LD pattern.

3. Processing Learning Designs

We now use the metadata presented in section 2 to describe various LDs obtained by graphic operations on an existing course. Figure 2 shows part of an OWL-DL ontology [6] in graphic MOT+OWL format that we will present further in section 4. The (I) link is the standard instantiation link between a class (here the LDs obtained from the same INF-5100 course) and one of its individual.

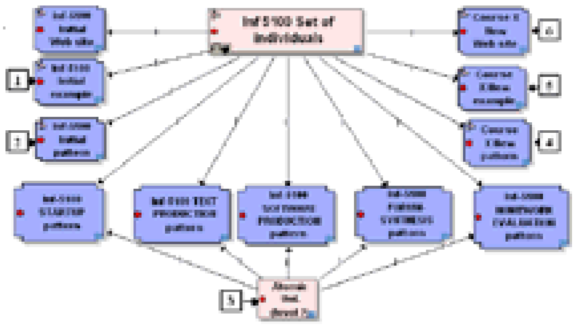

Figure 2 – Part of an ontology for a LD repository: a class of related Learning Designs

The numbers on the figures show the order of operations in a decomposition/aggregation process that was applied to an existing course on Artificial Intelligence at Télé-université labelled Inf-5100.

(1) The course was first modeled using the MOT+LD graphic editor as an IMS-LD Unit of Learning that was integrated in the IDLD repository.

(2) Using this editor, the model was stripped of its content by deleting all items to obtain a level 3 pattern, which was also added to the repository.

(3) This pattern was then decomposed into five level 2 "atomic UoL" patterns, each added to the repository.

(4) Using these level 2 patterns as activity structures, a new level 3 pattern (Course X) was aggregated and added to the repository.

(5) Content items have been added to this level 3 pattern to obtain a new level 3 course in political science. The corresponding manifest was generated and referenced.

(6) This new manifest was executed by the RELOAD player to deliver the new course.

These operations deserve some explanation that will help the reader understand how we have processed learning design graphically. Figure 3 shows the initial course play comprising eight acts. Each have sub-models (not shown on the figure) composed of roles, environments and activity structures. Act 1 sub-model is simple enough to be stored in the repository as one reusable activity structure, the "START-UP pattern" in step 3 of figure 2. Act 3, 5 and 6 are the same, stored as the "HOMEWORK EVALUATION pattern".

From Act 2, 4 and 6 sub-models, we have extracted two recurrent activity structures called "TEXT PRODUCTION pattern" and "SOFTWARE PRODUCTION pattern". Finally, act 7 yields the "FORUM-SYNTHESIS pattern" whose metadata have been described in figure 1. In MOT+LD, these sub-models are simply copied to a new LD structure and stored in the repository using PALOMA.

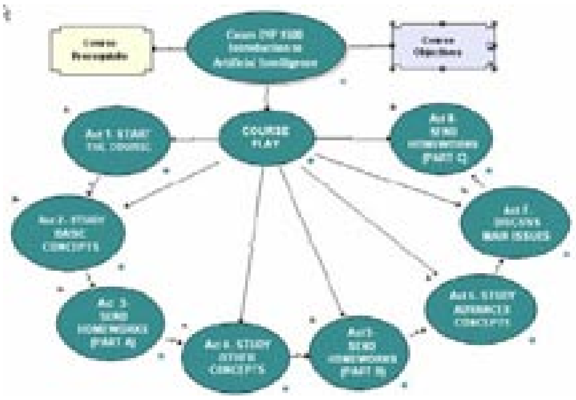

Figure 3 – The initial course

Afterwards, we search and retrieve these "atomic patterns" to group them in different plays and courses.

4. An ontology to manage the LD repository

To describe the relations between these different LD products, we have built a LD ontology to structure the repository. It embeds the classification, granularity level and relations described in section 2.. Figure 4 present the upper part of this ontology in MOT+OWL format. Classes are represented by rectangles and properties by hexagons. Here the graph shows the different section of the LD classification presented earlier with some added details for the central Cognitive Skills/Strategies sub-classes.

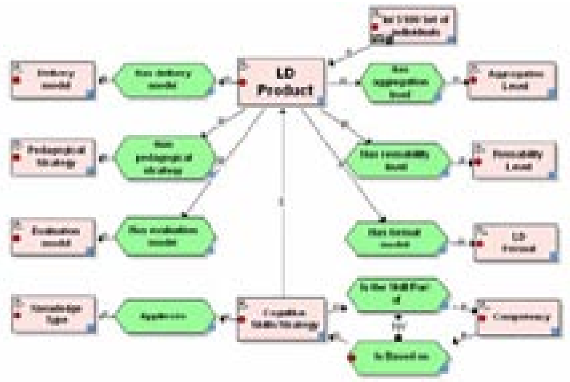

Figure 4 – A LD-products top-level ontology

On figure 5, the subclasses of the "LD format" classes and their main relationships are shown. A complete description and justification of this ontology is of course out of scope here.

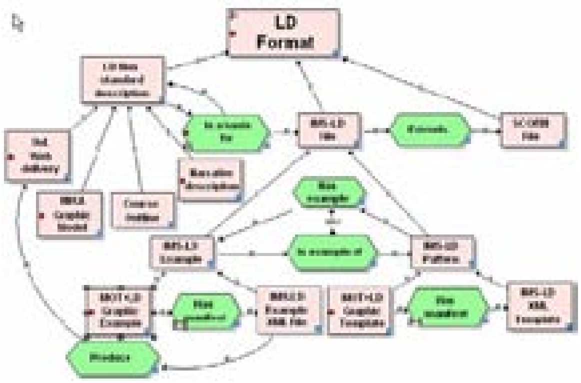

Figure 5 – The LD format sub-ontology

To this ontology we can add constraints that would enable users to avoid erroneous descriptions such as a so-called "synthesis" LD decomposed into UoLs that are all at the "apply" level. Using an inference engine on this ontology we expect to be able to query the LD repository in more meaningful ways than is possible now.

Conclusion

While populating the LD repository using the process in section 3, the graphic MOT+LD editor was found very helpful. It is easy to transform graphs, extract sub-graphs or regroup them, then add content items to create new learning designs.

Some problems occurred during the process. The new courses obtained by aggregating external UoLs must respect IMS-LD constraints that can be relieved in the graphic format. For example, items and environments can be added automatically by the graph parser into the manifest, thus easing the designer's task.

It is complicated and time-consuming to establish links between resources using PALOMA or any LOM manager. A specific interface can be built to aggregate together the LD editor and the LOM manager, both to add metadata to the LD components as specified by IMS-LD, and to describe LDs globally as learning objects as we have proposed here.

Automating the metatagging process can be made easier if we deduce metadata from the regular structure of an IMS-LD manifest and the proposed structure for a LD repository. For this a well-researched ontology must be shared by groups involved in LD research and deployment.

The IDLD repository has been built by the CICE team at the LICEF research center in Montreal with the collaboration of other Canadian researchers at Concordia University in Montreal, Simon Fraser University in Vancouver and the University of Waterloo in Ontario who have provided learning designs for the repository, as well as using and validating the tools. All the resources included are in the public domain using eCommons licenses. Télé-université is committed to sustaining the portal, hoping that new partners will make contributions to it or work with us on the issues presented here.

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PlanetDR, a scalable architecture for federated repositories supporting IMS Learning Design

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Abstract

This paper discusses PlanetDR, whose architecture supports very large federated educational digital repositories. It is based on the implementation of current open specifications for interoperability (such as IEEE Learning Object Metadata and IMS Digital Repositories Interoperability, in its Edusource Communication Language version), and its integration with the workflow of eLearning production in the context of the Reload Learning Design editor. This integration should support better re-use of resources; some open problems for enhancing further this re-use are also discussed.

Keywords: Federated educational repositories, Interoperability of learning objects, IMS Learning Design, Pedagogy-aware services.

1. Introduction

Historically, the development of standards indicates that a particular process or technology is maturing and has achieved a degree of commercial success. Nevertheless, in learning settings, the adoption of standards involves a slow process for both educational institutions and commercial companies (standards tend to come first!). Although some learning standards are now sufficiently mature, such as LOM [1] and SCORM [2], their widespread adoption in institutions and software packages is still a difficult and slow process.

As regards Learning repository interoperability standards, the problem is even stronger. Although a plethora of distributed content repositories have been implemented (for example Edutella [3], POND [4], Ariadne [5]), the lack of interoperability among them hinders universal content aggregation in a single worldwide repository. As a consequence, there exist isolated content islands full of tagged LOM contents that are only reachable to small communities.

In theory, the unifying standard that should enable server interoperability is the IMS Digital Repository Interoperability specification (DRI) [6]. The IMS Digital Repository Interoperability Group provided a functional architecture and reference model for repository interoperability. Aiming at very broad application of the specification the standard makes a recommendation only at a certain level leaving the resolution of more operational issues to the system implementers. This fuzzy specification leaves many open questions, and this mitigates against widespread adoption of a well-specified standard.

Fortunately, a Canadian network repository has proposed a concrete instance of DRI called Edusource Communication Language (ECL) [4]. PlanetDR has made a strong commitment to open standards and tools, supporting LOM and DRI, and is the first Open Source Learning repository that fully supports ECL.

Another proposal is the Learning Object Resources Interoperability Framework (LORI) [7] which is part of the PROLEARN [8] project. This distinguishes between core services and application services, both of which require a common messaging infrastructure which enables repositories to interact (XML-RPC, Java RMI, or WSDL/SOAP). In general, LORI follows a much simpler protocol than ECL and DRI, seeking to avoid the complexities of XQuery. This simplicity eases the implementation of LORI's SQI (Simple Query Interface) and thus lowers the burden of implementing Digital Repositories. On the other hand, it permits less flexible queries than DRI and thus limits content access and retrieval. LORI's SQI is a widely accepted interoperability protocol in European settings in the projects ARIADNE and ELENA [9].

Finally, MIT's DSpace [10] is another Open Source Learning repository that includes federation capabilities. Although Dspace is not based on open standards, MIT has attracted a large number of Universities to the Dspace federation. The possibility exists that DSpace could reach critical mass and become a *de facto* standard in learning repositories. In conclusion, in the coming years a key issue will be how LOM content islands such as those mentioned above can be integrated into a worldwide connected repository network. This will be the case whether it is based on de facto standards such as DSpace, or well-specified protocols such as DRI or LORI SQI. We propose that more scalable and robust technologies will be required to construct such large server federations. The structured peer to peer architecture developed for PLANET which we present in this paper meets this need.

Looking at LOM repositories from another perspective we note that the retrieval of materials from educational repositories is an isolated task in the educational workflow. This isolation can hinder the re-use of educational resources, which we may take to be the goal of interoperable repositories. The retrieval functionality supported by PlanetDR becomes more fully meaningful if integrated into the process of creating learning activities, as discussed in the second part of this paper. To this end the Planet repository has been integrated with the Reload [11] editor, a reference Open Source tool for the creation of Learning Design Units of Learning. IMS Learning Design (LD) [12] is a recent specification allowing the representation of how multiple learners and teachers can work with resources in different activities. As a result of the integration work reported here it is possible to work with RELOAD, and without leaving the application query PLANET repositories, retrieve resources, and seamlessly incorporate them into "lessons".

Finally, we discuss some open problems with the wider re-use of resources in this context. These include technical matters, such as the need for repositories to go beyond LOM based searching, and to provide full support for Learning Design based searches for resources, and also those of a more of social nature, such as supporting identification and re-use of the most successful resources.

The next section describes PlanetDR repository in detail, while the following section introduces LD and describes how Reload has been extended to deal with PlanetDR and the path to LD-aware repositories. The final section provides some conclusions.

2. PlanetDR content repository

The basic operation of a content repository is to provide the means for uploading resources, which are stored in a data warehouse. Later, these resources must be made accessible to registered users by allowing them to search contents by a broad variety of criteria.

When designing our content repository interoperability was a priority. We chose the Planet Digital Repository (PlanetDR) to implement the ECL protocol using web services. It also complies with the DRI interoperability specification, and both these specifications are described below.

3. DRI and ECL

The purpose of the Digital Repositories Interoperabilty specification is to provide recommendations for interoperating between the most common repository functions. These recommendations should be implementable across services enabling them to present a common interface. DRI utilizes already defined schemas, such as IMS Meta-Data, mainly based on LOM and Content Packaging (CP) [13].

The DRI specification takes into consideration that a wide range of already implemented content formats, implemented systems, and established practices already exist in the area of digital repositories. Consequently, its recommendations lay out into two categories:

Systems reflecting established practice (e.g. utilizing Z39.50 for repository interoperability).

Systems that are able to implement the XQuery and SOAP-based recommendations.

Focusing on the second alternative, which PlanetDR is based on, some core functions are defined as **web services**, which are exposed through the Internet, using SOAP, combined with WSDL (Web Services Description Language). This allows the content server to specify what services it provides, what the inputs/outputs of these services are, and how to encode/decode requests and responses exchanged between clients and servers. These core functions are described as follows:

Search/Expose: The search reference model defines searching through meta-data associated with content exposed by repositories. Searching is performed using the XQuery protocol over XML meta-data that follows the IMS Meta-Data Schema. XQuery has a well-defined grammar, and several commercial implementations are emerging from the community. Its strengths are query-by-example and structured searches of XML documents and repositories containing IMS meta-data.

Submit/Store: The submit/store functionality refers to the way an object is moved to a repository from a given network-accessible location, and how the object will then be represented inside that repository for access. The location from which an object is moved can be another repository, a learning management system, a developer's hard-drive, or any other networked location. It is anticipated that existing repository systems may already have established means for achieving Submit/Store functions (typically FTP). This specification provides no particular recommendations for legacy repository systems, but wishes to draw attention to the following weaknesses of FTP as a transport mechanism for learning objects or other assets: plain FTP provides no encryption capabilities, presents widely-recognized security flaws and does not provide means of confirming the successful delivery of assets from one networked location to another. In the case of more recently developed repositories that deal specifically with learning objects, this specification makes significant reference to the CP specification.

Request/Deliver: The request functional component allows users that have located a meta-data record via the Search function to access the content object or other resource described by this meta-data. Deliver refers to the response received from the repository which provides access to the resource.

Gather/Expose: The gather reference model defines repository-exposed meta-data requests, and meta-data aggregation for use in subsequent searches, or for creating a new meta-data repository. The aggregated repository becomes another entity available for Search/Expose functions. The gather component may interact with repositories either by actively asking meta-data from a repository, or by subscribing to a meta-data notification service. This notification service may be provided by the repository itself or by an external adapter that enables messaging between the repository and other users, thus following a push-based approach.

As mentioned above, one implementation of the DRI specification is ECL. This is part of the eduSource project, whose main aim is to create a network of linked and interoperable learning object repositories across Canada. Although previous projects had informally created a distributed network that allowed the search and retrieval of educational objects between projects and organizations, there was no formal discussion of any best practice for the future. A substantial part of the project has been the creation of communication protocols for sharing information as well as publishing the web services so anyone can tap their components into that pool of educational material and services.

Since the complexity of the ECL protocol might be detrimental to its adoption, an **eduSource connector** which implements the ECL protocol is provided. The connector provides a standard API to connect an existing repository to the eduSource network. The ECL protocol requires institution repositories or tools to implement connector handlers only for those services they want to expose to others, which is far simpler than implementing and deploying every service in each institution. The connector also facilitates version synchronization during the protocol evolution. Changes in the protocol itself rarely propagate to the API level. In most cases, repositories do not have to worry about the change in the protocol, they only need to update the connector with a newer version. Changes in the ECL protocol are detected by the newer version of the connector and are dealt with automatically.

4. Planet Digital Repository (PlanetDR)

Our educational content repository is called **PlanetDR**, and it is an implementation of the ECL protocol described above. The web services available include a search service, a submit service, and a request service. PlanetDR includes several search types: the *quick search* function allows searching for content keywords which match any of the meta-data fields for a particular content; the *advanced search* function can be split into two additional types as well: search by main meta-data category, where any LOM meta-data field can be specified, and the *accumulated search*, which allows searching for any field, linking together conditions of different LOM categories.

One interesting feature of PlanetDR is the possibility of invoking any web services from other content servers in the eduSource network. This is easily achieved because all of these servers follow the same ECL protocol. In this case, what we call a *federated search* (a simulated gather service) can also be conducted by linking together request results coming from all active content servers in the eduSource network. Nevertheless, the content server itself works as a standalone server, which makes it "unaware" of other content servers in the eduSource network. There is no way of easily knowing which other ECL content servers can interoperate with it. To solve this, the EduSource network linked servers by hand in a single central location. This approach clearly hinders the scalability of the federation if the number of servers increases.

To address this problem we have extended PlanetDR with a **federation mode**, using the **federation architecture** shown in figure 1. This mode which supports plug & play decentralized management of PlanetDR compatible servers, thus guaranteeing worldwide scalability. New PlanetDR active instances in the network are automatically detected and inserted into each node's local list of available servers. Each PlanetDR node listens to the different events which occur (insert / remove), and this allows each instance to maintain an updated list of available servers. Each server can join or leave the P2P federation of educational servers, and get a listing of all of them available in the network. Thus the federated mode maintains "awareness" of both the identity of the nodes which make up the network, and also of the content which they hold, so that directed searches can be sent to any of these nodes.

The overall PlanetDR federation architecture is scalable and can cope with a very large number of digital repositories because it builds on the FreePastry [14] structured peer-to-peer overlay network. Furthermore, PlanetDR is constructed on peer-to-peer middleware called DERMI, which was developed by the project [15]. This provides a decentralized naming service and remote object notification mechanism. This technology provides a distributed and decentralized discovery mechanism for incoming and outgoing PlanetDR nodes, and updates the current existing nodes in a decentralized manner. For example, any incoming PlanetDR node will be able to find all existing repositories in the system with a single lookup to the underlying DERMI..

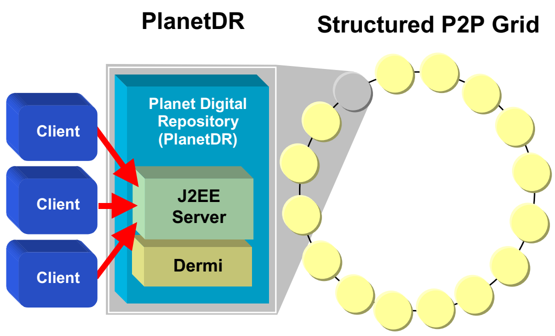

Figure 1. PlanetDR's Federation Architecture

5. Integration of PlanetDR and content creation

5.1 IMS Learning Design, Reload and the reuse of resources in context

The IMS Learning Design (LD) specification was produced to represent how multiple learners and teachers work with resources in different activities, a need not covered by SCORM, for instance. LD defines Units of Learning (UoLs) by representing how *people* carry out *activities* in an *environment* composed of learning resources and services. LD is a large and complex specification, and as a product of IMS it is by definition an interoperability specification, which does not constrain how eLearning applications should work, but only specifies an import and export format which they must be able to work with if they want to be LD compliant. At the risk of oversimplifying, a UoL can be seen as an interoperable lesson plan. In addition to being a file exchange format, however, LD is also an Educational Modelling Language, and a community of researchers working with LD has been established, building on the lead set out in the LD Best Practice guide [16] which proposes an eLearning methodology for the creation and use of UoLs. A set of applications has been developed to facilitate the creation and playing of UoLs using LD. All these aspects are reflected in the activities of the UNFOLD project [17] and interested readers can also find detailed information in [18].

Reload [11] is an Open Source editor of UoLs which sets out to be a *reference implementation,* that is to say that it implements the entire specification and provides a reference point for other developers who are in doubt as to how the specification should be interpreted. The very large number of downloads from the Reload website and the number of references to it in the published literature suggest that it has been successful in this. The equivalent Open Source implementation for runtime, the "reference player", is CopperCore [19]. In its current version, Reload supports a single user on a single machine program, whose inputs, such as resources, have to be locally available, and whose output is a zip file packaged according to the CP specification.

While PlanetDR supports search and retrieval of resources based on LOM and DRI, a much more natural working context is to perform this task when an author is designing a UoL, and to be able to include the resources retrieved in the UoL. Thus, we have extended the Reload editor to allow to search and retrieve resources from the PlanetDR repository, and include them in the workflow of UoL production. We describe next how this is done and discuss the benefits.

5.2 Connecting Reload to resources stored on PlanetDR

A new window has been added to the Reload editor that enables the user to specify the fields for searching the resources in the repository. These fields are name, keywords and format. According to the values provided by the user, the tool builds an XQuery statement, which is sent to the repository and executed. The results of the query are presented to the user, who can select one or more resources from the list and download them in a zip file, in order to use them in the UoL that is being designed. The zip file is a requirement related to the CP specification and contains not only the resource but also the metadata file.

The tool interacts with two of the web services of PlanetDR implementing the ECL protocol, *search* and *request*. The first is called in order to send to the repository a query specified in XQuery. The query is executed on the LOM metadata files of the resources in the repository, and the service returns a string containing the list of resources that satisfy the query. Secondly the *request* service is called in order to download the resource.

Due to the very complex and manifold nature of eLearning, the daunting task of providing interoperability specification has been broken into pieces, such as LOM, DRI, CP, LD, and others not mentioned in this paper. This simplifies the task of specifications implementers, and makes compliance more practicable. For the user, however, this may create difficulties, as it can cause unitary tasks (such as preparing a course module) to be divided into seemingly unrelated parts. The user needs to have these specifications transparently integrated in a workflow, and indeed in many cases the user should not be aware of the various underlying specifications. In our work we have integrated LD, DRI and LOM in the natural workflow for producing a UoL, showing that it is possible to make specifications more transparent to the user, and we believe this is a key step for usability.

Our work also indicates a possible path for performing this type of integration by re-using pieces of Open Source code, gluing them together through a web services approach. A general and open architecture for eLearning, which could be based on web services is discussed by Wilson in [20]; the SLeD project [21] has produced a prototype of such an architecture for LD allowing to plug new services (such as searching, blogging, …).

The CP perspective, which seems to have its origins in the ascendancy of CD-ROMs, makes difficult to make full use of distributed resources (which might have their own rhythm of updating), and forces local downloading, re-packaging. A much more natural perspective in the context of the Web is to link directly to the (distributed) resource(s). It may be that this can be achieved by fuller use of CopperCore. which is an LD engine that supports services, rather than a *player* as such. This is one of the perspectives of further work, which will follow an approach similar to that of SLeD.

6. Further perspectives for future work

Another perspective of future work is related to fully utilising the potential of LD and taking into account social use. Current approaches only use LOM, and reuse is limited to resources. The LD specification should support reuse of pedagogy, services, etc. As pointed out in [22] there is a need for repositories to have LD awareness. An LD-aware repository could support searches for UoLs that have been used with a certain kind of content, retrieve fragments of UoLs, or provide metadata on the use of UoLs. It is reasonable to suppose that teachers will not simply identify and use UoLs on the basis of LOM, but will also, and perhaps more importantly, base their decisions on the practice of the mass of their peers, or of individuals who they respect. Consequently popularity is one of the reasons why resources or pedagogies will attract use by others. Moreover, for the identification and refinement of successful practice it is also necessary for the history of use to be represented. As much of this as possible should be done automatically, as it has been clear for some years that most users are highly resistant to adding metadata to resources [23], and the EduSplash Repository [4] takes into account these aspects, beyond the EduSource project. Another approach, more related to popularity, is currently being adopted by the Lionshare project [24]. Automatic analysis can show teachers which resources are popular in their area / age group / curriculum. Lionshare is using the Shibboleth system developed by Internet2 to create flexible trusted communities and in such a context it may be possible to identify the individual teachers who have been using the resources, enabling teachers to emulate the practice of their successful peers. We intend to investigate how the reworkings of UoLs are associated with the UoLs on which they have been based, to permit browsing up and down the hierarchies of parents and children.

An interesting and quite different approach to the support which repositories can provide users of UoLs is provided in [25]. She suggests that it may be possible to use Latent Semantic Analysis and indexing in order to find concepts and similarities of concepts within a corpus of UoLs. The degree to which this promising idea will be practicable is not yet clear, as stated in her conclusions on the approach, setting out a number of questions for further investigation: "Can it be used to classify designs as good as well as bad practices, for example when user data, such as success or failure rates, completion time, etc are added to the analysis, or even with human classification of the design? Are acts the smallest independent units in learning designs? Are the templates sufficient for practitioners to develop new courses?"

7. Conclusions

In this paper we have discussed PlanetDR, which as well as being based on open specifications, such as LOM and DRI, has an architecture which can support the very large federated repositories of the future.

We have also described and discussed the implementation of the integration of the searching and retrieving facilities of such a tool into the actual workflow of eLearning production, which we deem as key for allowing the re-usability of resources, ultimate goal of repositories. We have discussed some open problems in this orientation of allowing the re-usability both from technical and social perspectives.

The modifications which we have made to the Reload LD Editor make a contribution towards expanding the functionality and improving the usability of repositories of eLearning Resources. It is, however, clear that this first step needs to be followed up by further work along the lines of future work which are indicated above.

Acknowledgments

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The OpenDock project: putting in place the infrastructure for sharing learning activities

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Abstract

The OpenDock project is introduced, and the approach to supporting the sharing of online educational resources outlined. The functional requirements for the OpenDocument repository are stated, and their significance discussed. The system which is currently being implemented is described. This is a light weight, open source, peer to peer system. The peer nodes are the users web presence, rather than their own computer, reducing the infrastructure requirements for small institutions and individuals. Support for IMS Learning Design is provided, with Content Packages being unzipped and stored as a hierarchy, and a parser provided to analyse the manifests and represent the UoLs. The effectiveness of the system in supporting sharing will be established in trials and demonstration activities in the OpenDock project.

Keywords: educational repositories, learning design, creative commons, peer to peer.

1. Introduction

The sharing of eLearning materials is not a simple matter, and for a review of the issues, see [1]. This is particularly true if the goal is to reuse learning activities and lesson plans in addition to learning resources. In an earlier paper [2] we argue that the use of Information Technology (IT) makes sharing harder than it was with paper based resources, and propose a framework within which the obstacles can be understood. The OpenDock project (www.opendockproject.org) seeks to stimulate the sharing of eLearning activities and resources in Vocational Education and Training (VET) by demonstrating how Units of Learning (UoLs) defined in IMS Learning Design can reuse learning resources and be shared between different institutions. This has involved the implementation of a repository designed to support the sharing of learning activities, and the first stage of this work is described in this paper.

There are many repositories which are designed to meet the needs of large educational institutions, which have their own powerful web servers, and technicians who can install and maintain software. Many smaller educational institutions do not have these resources, especially in the VET area directly addressed by the OpenDock project, funded by the European Commission through the Leonardo programme. Typically smaller institutions run their web through a web hosting service, and the task of establishing a permanent server to run a repository is a substantial one. This is still more true of individual teachers and learners who may want to run a repository. It is intended that any user who knows how to publish a web page will also be able to run the repository.

In this work we follow the analysis in [2] in identifying the need for revision of the functionality of eLearning resources repositories. It is not proposed that improved repositories will in themselves transform practice in sharing eLearning resources, but rather that they provide an essential element of enabling technology.

2. Functional requirements

In the light of this approach a set of functional requirements were developed, which are discussed below, with comments on their significance.

2.1 Support for Creative Commons Licenses

The copyright regime tends to restrict sharing of resources, not simply because resources protected by copyright cannot be shared, but also because users are deterred from sharing resources because they fear the possibility that they might be infringing copyright. The Creative Commons licenses [3] provide a legal framework within which individuals and institutions can share and adapt educational materials without fear of losing control of their own work, or of infringing the copyright of others. OpenDock has chosen to work exclusively with materials licensed under the Creative Commons in order to maximise the potential reuse of the materials developed. This has significant implications for the repository to be developed, as it is not necessary to provide a complex rights management system. Support for applying Creative Commons licenses is included in the system.

2.2 Use of Peer to peer technology

Peer to peer (P2P) systems such as Kazaar, eMule, and Limewire are hugely popular among users. Among the reasons for their popularity are:

- They are easy to set up, with point and click installers.
- They do not have heavy hardware and software requirements
- They are effective since, as is argued by LionShare, [4]"A key trait of P2P is that it optimizes network usage by distributing it throughout the community of network users and thereby avoiding bottlenecks".
- They enable the user to set up server without requesting the permission of a system administrator, making it easy for teachers and learners to set up their own nodes, for example in project based learning.

The advantages of these systems have not been exploited as much as they might have been because of their association with illegal file sharing. This is issue is addressed by the application of Creative Commons licences to all materials published on the OpenDock system.

2.3 Support for IMS Learning Design

ELearning interoperability specifications provide formal and structured descriptions of resources. These can be leveraged by the repository, which can use the description to provide additional information to the user. This is particularly true of a complex specification such as IMS Learning Design.

2.4 Mechanism to comment on posted items

Formal metadata will be supported, but when deciding whether to use a resource on a repository feedback from other users is also a key factor, especially if they are made by known and respected peers, or by members of the same professional community. Support for this needs to be incorporated into the repository.

2.5 Authentication and groups

The Creative Commons license provides defence against copyright infringement prosecution by shifting the burden of proof onto the person claiming the license. If credible complaints are received that certain materials posted are protected by copyright, then it is important to be able to bar offending users from using the system. Consequently only authenticated users should be able to use the repository.

It is also important that users can belong to groups, so that a) comments on resources can be classified, and b) users can give access to their materials to specific groups or users.

Searching and downloading of published resources from the repository may be done by anonymous users

2.6 Services made available

A number of exciting new eLearning applications are appearing which use a service based architecture, and which can broadly be classified as Personal Learning Environments (PLEs). Oleg Liber describes PLEs as an alternative to institutional systems based on courses, and which *locate a large amount of VLE functionality with the learner either as a desktop application or an independently hosted portal. Institutions would still provide content via repositories, undertake assessment and so on, but learners would interact with these using their personal systems (Personal Learning Environment), comprising their preferred tools and ways of working.* [5] Emerging systems include Plex (University of Bolton), Hecate (Open University of the Netherlands) [6] and Elgg [7].

3. System requirements

The functional requirements and user profile informed the identification of the following system requirements:

- Minimal hardware requirements imposed on users.
- Easy install, without root access. Preferably, installation consists of uploading the files to the server and configuration through a web-interface.
- Entirely Open Source system.
- Extensible architecture.
- Support for RSS, and have a well documented API.
- Web-based interface.
- Distributed network of smaller peer servers.

4. Existing systems

A state of the art analysis showed that while there are many excellent existing systems, none of them entirely meet the needs of the OpenDock project. The principal problems are

- **High system demands**. Existing systems often make use of java or jxta, for example [8], and they often have quite significant system demands, which makes it very hard to run them on shared servers. Some systems need an Oracle database, for example Ariadne [9] which make them relatively expensive to run and maintain.
- **Complex installation procedures**, often consisting of multiple steps, including installation of extra libraries and software. Often root access is needed for some steps.
- Architectural issues. Even with the P2P systems the architectures often required a strong IT infrastructure.
  - Some systems, such as Ariadne use industrial strength central servers to store files and metadata, and federate searches over a network of institutional servers. These searches may be federated over a larger network by using a protocol such as the ECL (EduSource Communication Layer). This approach is well described in [10]
  - More typical peer to peer systems can be installed on any computer with an internet connection, for example LionShare [11]. These systems have to choose whether to store metadata and files on one machine only, or to propagate them over the network. The LionShare default solution is to keep the resources only on the node on which they were posted, and to propagate the metadata. This means that to ensure a reliable service the nodes have to be hosted on a machine which will be always on, and has a good internet connection (although mirrors can be set up). Propagation of the resources through the network, on the other hand, quickly creates very large amounts of data on each node.
- **Missing essential functionality.** Only some of the existing systems have support for Creative Commons licenses, while support for IMS Learning Design is very limited. The exception is Planet which is integrated with the Reload LD Editor, making it easy for authors of UoLs to find resources from the Planet network (see Blat et.al at this workshop). Indeed the Planet system is perhaps that which most closely approximates to that required by OpenDock, the principal difficulty being that, like LionShare, it needs to be installed on a reliable computer with a good internet connection. Another aspect of support for IMS Learning Design is that described in [12], which focuses on the use of ontologies to integrate learning designs with content.

5. Proposed solution

A small distributed web-based open source repository system called OpenDocument.net.

5.1 Architecture

As described in the previous section, prior P2P systems make demands on infrastructure which cannot be met by many of the target users of OpenDock. The problem is resolved by taking an approach which is similar to LionShare (for example), in that the metadata is propagated, but not the resources. However in our case the user's computer is not used as the peer, but rather a web presence. This may be an institutional server, but may more typically be rented web space. The only requirement is that the server be able to run PHP. In this network of rather independently functioning repositories, it does not harm the system if one particular repository fails to function. All repositories contain only the files that were uploaded to them and on top of that the meta information about content at other nodes. In this way all the repositories are aware of the available content in the network, but there will be no integrity violations or racing conditions involved. If one node fails the system continues to function, although the other nodes will notice the failure and inform the user. This is similar to the Internet, which does not go down if a few servers malfunction.

Similarly this approach favours scalability (because only small metadata files are replicated over the network). Performance of any given node will depend on the choice of server made by the people who set it up. This enables institutions to make their own decisions about the quality of service which they wish to offer, the amount of files they want to share, and money which they want to invest. This decision can be delegated to the individual nodes because the performance of the network is independent of the performance of single nodes.

The solution consists of three parts:

- Repository Server
- Repository API
- Default user interfaces.

The logical model in which the data is stored consists of four levels:

- Network
- Repository
- Container
- Item

In this model a network consists of a number of repositories that replicate metadata and exchange information about their content. All content is stored in the Repository as items in a container. This could be a folder with images, a set of documents or a UoL with resources and a manifest file. Many repositories can only store one file at a time, either as separate entities, or as a zip file. In this approach complete directory structures can be stored, making it easier to handle HTML sites. Similarly a UoL uploaded as a zip file is expanded out to a directory structure, so that it can be searched and individual items returned in searches. It can be reconstituted as a zip file for delivery to the user. This architecture should provide a system which is easy to install and maintain, but which does not sacrifice scalability.

The name OpenDock.net recognises the relationship between this solution and the OpenDocument standard which is used in the OpenOffice toolset. In this standard the files are not considered as atomic units, but rather a collection of items. The way in which we organise the content in the repository is largely based on the ideas embodied in the standard, and the name OpenDocument.net has been chosen to make this association explicit.

5.2 Repository server

The server is a lightweight object oriented PHP application that can run on any web server which supports PHP and mySQL. Development and testing is being carried out with Apache. As stated above, it is intended that installation should be a straightforward task for anyone who knows how to publish a web page. The procedure consists simply of unpacking an archive (typically a zip-file) at the server site. Upgrading involves essentially the same process, the new files are unpacked and the upgrade is done.

Backing up is provided as a standard service by all hosting providers, but we also intend to build an administrative tool that backs up the whole repository in one or two files that are available for download to the administrator. This will also enable the state of the repository to be documented at any given moment. Restoring a consists of setting up the repository in an inactive state, and downloading or uploading the appropriate zip-files and unpacking them. If the database also needs to be restored too, a script is run to insert the meta data of the backup into a new database. This will be a simple two or three step protocol that is easy for the responsible administrator to perform. The system maintains data about the size of all the items and the repository as a whole. If the memory space limit of the server is reached, the user will be informed that uploading new content is not possible.The server has no built-in user interface. It consists of a core with a clearly defined API.

The server uses XML-RPC (www.xmlrpc.com) as a remote procedure protocol. This uses XML to encode its calls and uses HTTP as a transport mechanism. For added security the server makes use of HTTPS (HTTP encrypted by SSL or TLS protocols) for all external communications.

All items in the repository are stored in the file system where the server is installed. Metadata, user information and system information are stored in a database.

5.3 Repository interfaces

Initially the repository will come with a simple web-based interface application in PHP. This interface uses XML-RPC to communicate to the API of the Repository Server. The default web-interface will also be able to output RSS for aggregation to other (web)applications.

A clear API document will be available for developers willing to create their own interfaces to the Repository. Other potential interfaces could be connections from existing IMS Learning Design applications such as Reload or SLeD, or components for LMSs and CMSs such as Moodle, Joomla and Plone.

5.4 Authentication

Each repository instance maintains its own userbase. Users of a repository have access to their own repository and are able to add comments and metadata to other repositories in the network. The repository has an Access Control System (ACS) based on users, groups and rights.

5.5 Distribution

Information about the contents of a repository is replicated to other instances in the network. Replication will be done regularly or triggered by users with sufficient rights.

5.6 Support for open specifications

Currently planned IMS LD support for the OpenDocument Repository will leverage the storage of the zipped Content Package as one or more containers with the constituent files. This gives the user access to the individual resources and stimulates reuse. The Repository will have a built-in LD parser which can generate a simple preview/overview of the UoL, and make LD properties such as level, prerequisites, objectives etc. available for searches. The parser is a plug-in, and so it would be easy to later include support for other specifications, such as QTI or SCORM.

Support for LD authoring, such as that available for Planet, would also be desirable.

Items in the repository can be stored under Creative Commons licenses. The user uploading or creating a new item or container chooses the required license from the user interface. Creative Commons license information is also available for searches. The default interface will be able to generate RSS feeds from the Repository. Possible applications are: popular items, newest items, latest comments, etc.

5.7 Support for discussion

Users will be able to comment on items or containers, and their input will add to the metadata around the resource. Users also will be able to rate items.

6. Conclusion

The OpenDocument repository is currently being implemented, and trials are scheduled to start with end users in October of 2006. Its light infrastructure demands, simplicity, support for IMS Learning Design and Creative Commons, and service orientation are a unique combination of features which will hopefully make it possible for small institutions, and individual teachers to establish reliable educational repositories without major investments of time or resources, and to establish effective practice in collaboration. This will be tested in the OpenDock project during the second half of 2006 and 2007. Those beyond the project who would like to participate in this process are encouraged to contact the project by writing to opendock.info@upf.edu

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Using IMS Learning Design to Model Curricula

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Abstract

The traditional notion of the curriculum as a fixed list of topics to be studied sequentially is under strain as pressure for flexibility in education increases. However, curriculum flexibility can lead to curriculum complexity, hindering learners in the development of their competences. This article presents a formal model for the description of curricula, designed to underpin guidance support systems for learners. The article compares the model to other work in the area, illustrates its application with a number of case studies and concludes with a discussion of the broader e-learning infrastructure required in implementing the approach.

1. Introduction

A standards-based IT infrastructure is now in place in educational institutions around the world, simplifying the delivery equation and opening the doors to mainstream, large-scale, web-based education [1] and offering the possibility of increased curriculum flexibility [2]. Traditionally, educational systems have shown a rigid character, with learners being grouped into cohorts for fixed-length programmes with pre-determined start dates and pre-determined structures [3]. In contrast, flexible systems are designed to allow learners "to follow open learning pathways of their own choice, rather than being obliged to follow predetermined routes to specific destinations" [4].

Credit and modularisation play a central role in achieving this freedom [5]; modular educational systems revolve around units which can be combined (i.e. sequenced) by learners to reach educational goals. However, the flipside of modularisation is complexity. Yorke [6] highlights that "as the unitization of curricula spreads through higher education, so there is a need for greater guidance for students to navigate their way through the schemes". This point is also raised by Gledhill [7] who notes the complexity inherent in modular programmes and the difficulties this implies for advice-giving.

These difficulties can be seen at the website of the PLOTEUS initiative [8] which aims to help students, job seekers, workers, parents, guidance counsellors and teachers find out information about studying in Europe. Although extensive in its coverage, the portal presents learners with a bewildering assortment of learning opportunities, each leading the enquirer to the vagaries of providers' websites. In the absence of a standardised approach to describing the curricula related to the opportunities, learner guidance in the form of directions for progression is costly and piecemeal. This articles starting point is that a standardised language for modelling curricula would ease the development of automated guidance systems in e-learning.

2. Curriculum Modelling Requirements

Requirements for the modelling of curricula can be found in the curriculum design literature [9-12], lifelong learning policy documents [13, 14] and literature on credit accumulation and transfer [15-17]. We summarise the requirements in the following points:

- *Modular composition*: Curricula must be able to be constructed from units. Example: in order to reach competency level 3, modules 45a, 33d and 67t must be successfully completed.
- *Nested composition*: Curricula must be able to be composed of other curricula. Example: the Course can be divided into two phases: the propedeutic phase and the post-propedeutic phase. The former consists of the following modules …
- *Selection*: It must be possible to specify which elements of a curriculum are mandatory and which

are optional. Example: Students must complete module H101, and may select any two modules from H101, H103, H104 or H105

- *Sequencing*: it must be possible to specify constraints on the order in which elements of a curriculum are to be completed. Example: Students must first complete module "L-A4 An introduction to linguistics", before being allowed to commence module "L-G5 Psycho-linguistics"
- *Completion*: The requirements for completion of a curriculum element, and of the curriculum itself, must be able to be specified. Example: Each module carries a specific credit value. Students need to accumulate 60 credits from the optional modules in order to progress from the propedeutic to the post-propedeutic phase.
- *Conditional Composition*: It must be possible to specify conditions under which curriculum elements are to be included or excluded. Example: Applicants whose mother tongue is English are not required to complete module E101. Example: Students who have completed the introduction to Psychology are not required to complete the History of Psychology course. Example: Learners who do not elect to follow the statistics course are required to follow an additional introduction to algebra course in the elective phase.

Furthermore, drawing on the educational modelling approach used in [18], we add the following generic requirements:

- *Formality*: the language must describe a curriculum in a formal way, so that automatic processing is possible.
- *Interoperability*: The language must support interoperability of curricula so that different support systems can share and exchange information.

3. Related Work

There are a number of existing approaches to specifying what needs to be done by learners to achieve educational goals. The European Credit Transfer and Accumulation System or ECTS [19], is a systematic way of describing the student workload required to achieve the objectives of an educational programme (e.g. 'students must accumulate a total of 60 ECTS credit points'). ECTS is, however, not a formal modelling language and does not provide a means of fully specifying curricula (e.g. there are no constructs to describe sequences and selections using ECTS). The National Open College Network Credit and Qualification Framework's Technical Specification for Qualifications [20] does include the notion of Rules of Combination describing mandatory and optional units. However, as yet, no formal modelling language is used for the specification of the rules, limiting the opportunities for automated processing.

Significant research in curriculum modelling has been carried out over the years in the area of Intelligent Tutoring Systems [21, 22]. While this work has a formal basis which meets the generic educational modelling requirements described above, approaches to curriculum modelling in the ITS worlds have tended to involve the modelling of conceptual domain knowledge (what is related to what in the domain) and the modelling of knowledge pre-requisites (what must be learned before what) so that automatic planning processes can perform curriculum sequencing. We view this as a far deeper and correspondingly more taxing level of modelling than is required for guidance. Rather than modelling domains, a more pragmatic approach may be to model UoLs about the domains, and to use this information during guidance.

Finally, work on the eXchanging Course-Related Information [23] reference model is drawing on a number of other international initiatives, particularly from the Scandinavian countries, to define a vocabulary for describing course-related information encompassing course marketing, course quality assurance, enrolment and reporting requirements. This is interesting work in progress, albeit with a scope which is slightly different to that of the work described in this article, focusing more on institutional publication of course information to diverse audiences rather than the learner guidance problem. However, the XCRI reference model includes some facilities for modelling curricula which we believe could be usefully extended with the constructs included in this article.

4. IMS Learning Design as a Curriculum Modelling Language

Another candidate for a curriculum modelling language is IMS Learning Design [24, 25]. IMSLD provides constructs allowing instructional designers to specify which roles should carry out which activities, with which supportive learning materials and services in order to achieve learning objectives. The bulk of the literature on IMSLD has addressed its application to

the modelling of the internal structure of UoLs at a micro level for subsequent 'playing' in a Virtual Learning Environment. However, the specification permits varying levels of granularity of a unit of learning, referring to "any delimited piece of education or training such as courses, modules or lessons"; a (macro) unit of learning can be defined in terms of other UoLs to describe curricula. Using IMSLD in this way at the macro level does not require its full sophistication, simplifying the modelling task.
Given its pedigree as an educational modelling language, IMSLD would seem a suitable candidate for a curriculum modelling language. Table 1 illustrates how the requirements identified above are met using the constructs of IMSLD.

Modular composition	A UoL can reference another UoL within an activity structure through a uniform resource identifier. We note here for completeness that the text of the IMSLD specification contains a technical restriction in the area of inter-UoL referencing but which is not formally enforced in the associated XML schema.
Nested composition	Activity structures can be nested, thereby allowing nesting of UoLs
Selection	The type of an activity structure can be indicated as a *selection* indicating that the elements of the selection may be done in any order. Moreover an attribute can be specified (number-to-select) to indicate how many elements of the activity structure must be completed before the whole activity structure is considered complete (e.g. four of the six specified possibilities, one of the seven etc).
Sequencing	The type of an activity structure can be indicated as a *sequence* indicating that the elements of the selection must be done in the specified order.
Completion	IMSLD has an expression language through which complex rules for completion can be defined.
Conditional Composition	The expression language can also be used to describe conditions based on various types of properties (of the learner, the curriculum, etc).
Formality	IMSLD is described using the XML Schema formalism allowing various types of processing to be brought to bear on information modelled using the specification.
Interoperability	IMSLD is an open specification published by a consortium which promotes e-learning interoperability.

Table 1. Matching IMS LD against the curriculum modelling requirements

5. Case Studies

In order to investigate whether IMSLD is suitable for modelling curricula, three sources of programmes were used. First, the distance teaching programmes offered at the Open University of the Netherlands were analysed. Second, an analysis was made of a selection of curricula found via the PLOTEUS service. Finally, a set of learning programmes which can be found on the Internet was analysed.
A sample of the results of the analysis is shown below, whereby the description of the programme is matched with a textual description of its mapping to IMSLD (XML code is excluded for clarity).

- Bachelors degree programme in Dutch Law
    - The Bachelor programme in Dutch Law consists of 42 modules and is divided into two phases: the propedeutic phase (14 modules) and the post-propedeutic phase (26 modules). The former begins with an introductory course in Law (which counts for two modules) after which students follow the remaining 12 modules in any order. The modules of the post-propedeutic phase can be followed in any order. The bachelor is completed with a compulsory "integration practical" which counts for 2 modules.
    - The UoL representing this curriculum consists of an IMSLD Activity Structure (AS) which is a sequence, containing nested ASs for both the propedeutic and post-propedeutic phases, followed by a UoL representing the practical. The propedeutic phase is a sequence which starts with the UoL for the introductory course and is followed by a nested AS representing the remaining 12 modules (a selection). The

  post-propedeutic phase AS is a selection of the 26 modules.

- European Computer Driving Licence, e-citizen programme [26]
  - e-Citizen is the new end-user computer skills certification programme from the European Computer Driving Licence (ECDL) Foundation. The programme is designed to cater for those with a limited knowledge of computers and the Internet but who wish to gain valuable everyday computer and Internet skills. The e-Citizen Syllabus has been defined by the ECDL Foundation in three blocks which are followed in progression: Block 1: Foundation Skills, Block 2: Information Search and Block 3: E-Participation. Each block consists of a number of topics (e.g. The Computer, Files and Folders)
  - A UoL is defined for each topic and grouped into an AS per block (selection). These three ASs are included in a sequence AS, ordering the blocks in the correct sequence.
- Driving Goods Vehicles National Vocational Qualification [27]
  - The Level 3 Qualification is for drivers who can show broader driving competencies and be considered as professional goods vehicle drivers. Drivers must obtain all 8 mandatory units, plus at least any 2 optional units from 4 specified for a full award.
  - This programme again follows the pattern of two ASs, one dealing with mandatory modules (selection), the other dealing with elective modules (selection, number-to-select=2)
- University of Washington Certificate Program in Aircraft Composite Materials and Manufacturing [28].
  - This online learning programme targets employed engineers and others who cannot take courses on campus. Coursework must be completed in order, beginning with Aircraft Composite Materials, followed by Aircraft Composite Manufacturing. Thereafter, learners choose one of two elective courses: Aircraft Composite Tooling or Aircraft Composite Repair
  - This certificate programme is modelled with an AS of type sequence, which orders the first two modules, followed by a nested AS of type selection (number-to-select=1) containing UoLs representing the two elective modules
- UK National Vocational Qualification for Registered Manager [29]
  - The qualification is intended for managers, assistant managers and others who have managerial responsibilities within regulated care services. All four mandatory units, one unit from each of the four optional groups and two units from any of the optional groups are required for successful completion of this NVQ.
  - Although seemingly comparable with the examples described above, this curriculum requires a higher degree of sophistication of IMSLD modelling. The mandatory units are dealt with using an AS of type selection. Learners' constrained picking and mixing from the four optional groups is handled using conditions. An AS containing all 16 optional modules is defined, together with a number of conditions. The conditions track whether one UoL from each group has been completed and whether 2 additional UoLs have been completed.
- B.A. in Computer Science - Systems & Applications Computer Science (OUI, 2006).
  - Students must accumulate 29 credits from the required modules and 14 credits from the elective modules. Those who have already taken Formal Automata Theory may not take Automata Theory and Formal Languages and must therefore accumulate 31 credits from required courses and 12 credits in electives in Computer Science
  - The heart of this curriculum is straightforward to model using activity structures. IMSLD conditions are, however, required first to track the ongoing accumulation of credit points (since course completion depends on a credit total rather than on a number of completed modules), as well as to adjust the total needed from the required modules depending on information on the learner's course history, excluding the relevant course (in IMSLD terms, using HIDE) appropriately.

The seven case studies cover the various curriculum modelling requirements listed earlier in the paper.

6. Discussion

IMSLD's ability to sequence, select and nest various combinations of units of learning, together with its condition language provide a suitable base from which to tackle a variety of curriculum modelling issues.

Although many approaches, languages and formalisms exist in which curricula could be specified (e.g. word processing documents, Java programs, HTML), IMSLD's nature as an open specification, published by a non-profit organisation committed to its maintenance and with a growing set of development tools, make it an attractive solution to the curriculum modelling problem; using it avoids the need to develop a new language to underpin learner guidance support systems.

Clearly, adopting IMSLD as a curriculum modelling language requires other pieces of the e-learning interoperability jigsaw being in place for the approach to work:

- E-learning modules which are addressable as UoLs and able to be referenced from other UoLs.
- Learner record systems, or e-portfolios, so that conditions can be defined in terms of their content;
- Infrastructure to record in the above systems that a UoL has been completed, propagating this fact to associated systems;
- Agreed naming conventions for competences, again so that conditions can be created
- A curriculum processing engine, which, given a curriculum modelled using IMSLD and information on the learner, is able to compute what remains to be done by the learner to reach his or her educational goal.

Further analysis is needed on the implications of curriculum lifecycle management to confirm that IMSLD's expression language offers all the constructs needed to deal with versioning, splitting and merging of UoLs over time. In addition, a separate research strand is needed on visualising curricula, particularly in cases of complex nesting of activity structures and high degrees of optionality. Such additional work is needed to support both the appropriation of curricula described by Rasseneur et al. [30] and the usage analaysis described by Barré et al. [31].

The next step is to apply the approach in pilot learning situations built upon the appropriate infrastructure (e-portfolios, positioning services etc) to gain additional feedback on its applicability.

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Integrating IMS Learning Design and IMS Question and Test Interoperability using CopperCore Service Integration

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Abstract

Abstract. This article describes a framework for the integration of e-learning services. There is a need for this type of integration in general, but the presented solution was a direct result of work done on the IMS Learning Design specification (LD). This specification relies heavily on other specifications and ser-vices. The presented architecture is described using the example of two of such services: CopperCore, an LD service and APIS, an IMS Question and Test Interoperability service. One of the design goals of the architecture was to minimize the intrusion for both the services as well as any legacy client that already uses these services.

1. Introduction

This article describes the design and implementation of a generic integrative service framework, called CopperCore Service Integration (CCSI) [1], for the IMS Learning Design specification (LD) [2]. This work was done as part of the JISC ELF [3] [4] toolkit strand project called SLeD2 [5] as a joint effort of both the Open University and the Open University of the Netherlands. The project extended earlier work which involved building an LD runtime service and a corresponding web based client application called SLeD.
The LD runtime service, called CopperCore [6-8], processes units of learning (UOLs) which are IMS content packages containing a learning design defined in LD. CopperCore does not make any assumptions about the type of user interface used by the calling party. This allows CopperCore to be integrated in web clients as well as rich client platform applications. In fact, CopperCore does not provide any user interface at all, and all methods are only available through an Application Programming Interface (API). Therefore CopperCore cannot be used as a standalone product and must be used as a service integrated into a larger framework or Learning Management System (LMS). CopperCore relies on the provisioning of other services by this framework or LMS for parts of the LD processing.
Some of the services on which CopperCore relies are generic and may be used by other services as well. Examples of such common services are authorization and authentication. Although technically challenging, these types of services are not the focus of our work as they apply to all service oriented architectures. However, there are a number of e-learning oriented services that are tightly integrated with the LD specification that provide our focus. Typically, these can be found in the *service* section of the LD environment. Note the LD term *service* refers to the functional concept of a learning service supporting a user in the learning process. The LD term *service* does not refer to the technical notion of a service as in the term web service although the technical implementation of a LD *service* could well be achieved by a web service. The LD specification includes a number of services such as a mail service, synchronous and asynchronous conferencing service and an index and search service. LD also allows additional services to be specified when needed.
Furthermore LD specifies how other IMS specifications should be integrated. Examples of such specifications are the IMS Question and Test Interoperability specification (QTI) [9] and the IMS Simple Sequencing specification. Although these specifications are quite clear on the authoring aspects of their integration, they are not particularly clear on

their runtime aspects. An example is the integration of QTI items in the unit of learning. During runtime there must be a means of reacting to outcomes of QTI assessment items within the learning design workflow.
These implications are not well understood. The CCSI framework provides an extensible solution for the tight integration of loosely coupled services. The cross service concerns in particular are targeted by CCSI, alleviating the calling process from the burden of dealing with these concerns. In the remainder of this article the CCSI framework will be further elaborated by focusing on the integration of the CopperCore service and a QTI service which is called Assessment Provision through Interoperable Segments (APIS) [10]. APIS is an implementation of a computer aided assessment service conforming to QTI and is also funded under the JISC ELF toolkit strand.

2. Integrating IMS Learning Design and QTIv2

With the release of the second version of QTI guidelines for the integration of LD and QTI were described [11]. The integration of LD and QTI revolves around aligning LD properties and QTI variable names. Essentially, when property identifiers and variable names are declared to be lexically identical at design time (i.e. in LD-based and QTI-based XML), they are considered to be a *shared variable* in run-time software environments that involve LD and QTI-based processing.
One implementation strategy for the guidelines above could be to build an integrated system combining the functionality of both the CopperCore and APIS service. However, given the considerable efforts that have been invested in the CopperCore and APIS services, this may not be an economically viable solution. Another approach would be an adaptation of both CopperCore and APIS allowing them to directly communicate with each other. This approach has two major drawbacks. First of all this introduces undesired dependencies between services. Secondly, this solution is not scalable as each new service being integrated requires an ever growing integration effort required to support communication with all the others. In the next section the architecture for CCSI is described that has none of the above drawbacks, together with a number of benefits.

3. CopperCore Service Integration Architecture

In order to make the service integration viable it is essential that the underpinning architecture is not intrusive, meaning adaptation to this architecture should only require minimal changes in the code of the existing services, like CopperCore and APIS and the existing clients using these services. Service and client implementers are unlikely to make it a priority to adapt their code solely for CCSI.
By the introduction of an intermediate service layer composed of a dispatcher and adapters we can meet the above requirements. Each adapter is a software component encapsulating a single service implementation. The dispatcher is the central component, responsible for the orchestration between these services. To make this orchestration possible, all adapters share a common API providing the dispatcher a standard interface to all integrated services. Each adapter implements specific code to access the underlying service by implementing this common interface. This way the required code adaptations needed for the service integration are now encapsulated in the adapters, leaving the services untouched.
For each type of service (LD services, QTI services or conferencing services) multiple implementations may exist. In order to make these service implementations interchangeable a contract between the client and the adapter is introduced for each service type in the form of an interface. This interface describes the common functionality for these service types. Adapters are allowed to extend this functionality by exposing the complete API of the underlying service implementations. Not only does this provide a richer system, it also makes the adapter transparent for any client using the original service. However, clients that make use of the extended functionality will need to be modified when another service implementation is used that does not provide this functionality.
Each interface is accompanied by an abstract adapter. Each abstract adapter implements the default hooks for the dispatcher. This alleviates the implementers of specific adapters from re-implementing these hooks over and over again.

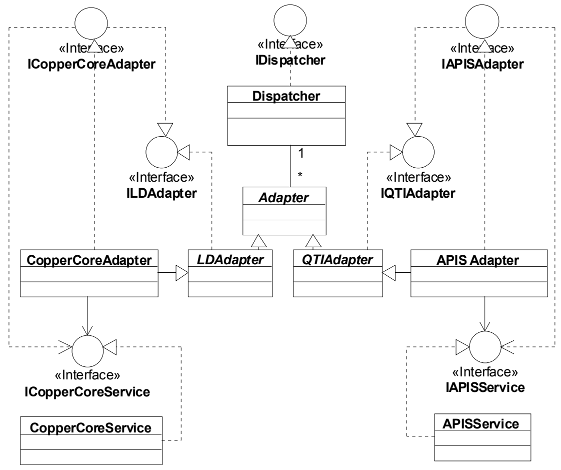

Fig. 1. CopperCore Service Integration architecture

Fig. 1 depicts the CCSI architecture. The *Dispatcher*s most important role is the propagation of events through all defined adapters. It is the responsibility of the adapters to listen for these events. Vice versa, it is the responsibility of each adapter to trigger the *Dispatcher* when an event occurs that has potential cross service repercussions.

The *Dispatcher* is also responsible for returning an adapter of the requested type to the client, thereby acting as an adapter factory. This adapter factory is necessary because the types and implementation of the adapters are not known in advance, and may vary even during deployment by simply adding or replacing adapters. Adapters can come in two flavors depending on the way the client wishes to access the adapter. This can be done either via native Java calls or via SOAP web services. For a native Java call the dispatcher returns an instance of a Java class. For a web services it returns a URL to the WSDL of the requested adapter. All adapters are declared in the CCSI service definition file. This file contains information about the base service type, the implementing Java class and WSDL URL.

Furthermore Fig. 1 depicts two adapter types; an adapter for the LD service and an adapter for the QTI service. Note that there could have been additional adapters for other services as well. The common interfaces for these service types are defined by the interfaces *ILDAdapter* and *IQTIAdapter*. Each adapter must implement the interface for its base type. The figure also shows two abstract classes *LDAdapter* and *QTIAdapter* that are abstract classes implementing the hooks for the *Dispatcher*. They are the extension points for any adapter acting as façade for either an LD or QTI service implementation. Both the *CopperCoreAdapter* and the *APISAdapter* provide an interface that can be used by client applications. This interface is a replication of the original interface provided by the service that is being integrated, hence the dependency relationship between *ICopperCoreAdapter* and *ICopperCoreService* and between *IAPISAdapter* and *IAPISService*. By maintaining this relationship between the interfaces the impact for existing clients migrating to CCSI is limited to a minimum. Vice versa, when a service implementation is modified the impact is limited to the adapter acting as the façade for this service.

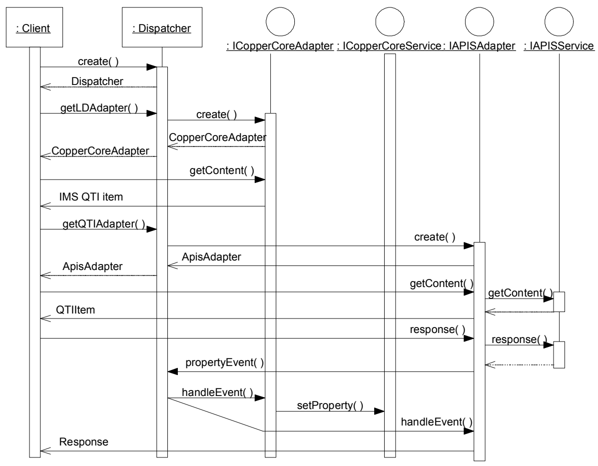

Fig. 2. Sequence diagram showing the processing of a QTI item and the resulting event handling by the dispatcher.

Fig. 2 depicts a sequence diagram representing the processing of a QTI item within the context of a UOL run. The client (e.g. SLeD) creates a new instance of the Dispatcher. The Dispatcher reads the CCSI service definition file and is informed about all available adapters. In the case of the example we only have the *CopperCoreAdapter* and the *APISAdapter*. Next, the client will request a handle for an *LDAdapter*. Depending on the technology used, an instance of the CopperCore adapter or a URL to the WSDL of the CopperCore adapter is returned. The Dispatcher provides the client with an identical API in the *CopperCoreAdapter* compared to the original CopperCore service. So legacy clients, like SLeD, only have to be modified . At some stage in the process the client retrieves QTI content and reacts by requesting the Dispatcher to provide a handle to a QTI adapter. In our example the handle for the APIS adapter is returned. The client makes a request for the rendered content of the QTI item to the APIS adapter. The user response to this item is passed on to the APIS adapter. The APIS adapter processes this response, which

results in a change of one of the variables defined by the QTI item's response section. It is the responsibility of the *QTIAdapter* to notify the Dispatcher about this property event. In turn the Dispatcher will propagate this event to all defined adapters that have registered as listeners to this particular type of event giving them a change to react to this event.
In order to synchronize the value of the QTI outcome variable, a corresponding LD property needs to be defined in the UOL. The CopperCoreAdapter will verify if this property exists and if so the value of the LD property will be set to the value of the QTI outcome. After all adapters have been informed about the property event, the result of the APIS adapter is finally returned to the client.

4. Integration of other Services

CCSI was developed with the integration of different kind of services in mind, especially those defined in the service section of LD although other types of services are conceivable too. In fact, in SLeD2 a number of adapters for these services were developed such as a search adapter and a conference adapter. The principle of integration is exactly the same as was done for the QTI adapter. However the type of events that are dispatched may differ. For example, for the conference adapter it is relevant to be informed about new runs [12] being created for a UOL. A run is a runtime instantiation of a UOL and involves the enrollment of individual users to the defined roles in the UOL. Similarly, it is relevant for the conference adapter to be informed about user subscriptions and role changes within the run of a UOL. The events are generated by the CopperCore adapter and can be picked up by a conference adapter.
Although the design of CCSI started from a need to establish a close integration of learning services in CopperCore, the resulting architecture in fact supersedes this requirement by offering an approach that allows the integration of all kinds of services even if they are not directly LD related.

5. Related Work

In the field of learning service integration some interesting related work has emerged. The IMS Tools Interoperability Guidelines (TIG) [13] is worth mentioning here. TIG deals with the interoperability of tools and LMS and is a first attempt to any standardization in this area. It shows some resemblance to the solution presented in this paper although there is a significant difference. The focus of SIG is mainly on technical aspects of the integration and less on the functional integration of the different services. TIG will not deal with any functional inter service dependencies, like the orchestration of property values between services, as shown in our example.
Another interesting, closely related development is the Business Process Execution Language (BPEL) [14] for Web Services. BPEL primary focus is the orchestration of SOAP web services. All logic for this orchestration is declared in an XML file which is interpreted by a BPEL engine. Recently tools for BPEL, like engines and editors have become widely available, which was not the case when work on CCSI started. Although BPEL holds some promising advantages over the presented approach, it is doubtful if the extra overhead introduced by the use of BPEL can be justified for the rather light weight integration of the services presented so far. Especially in cases where services are not SOAP compliant the presented approach could have significant advantages.

6. Conclusion

Interoperability specifications like LD and QTI are having an ever growing impact on the e-learning community. As a result the number of implementations is steadily growing; initiatives such as the JISC ELF have demonstrated this via the delivery of several services dealing with these specifications (e.g. APIS and CopperCore). However at the same time, runtime inter-specification operability issues are not yet understood. In this article, an approach was presented that deals with the interoperability of e-learning services within the context of LD. As the basis for the presented solution two service implementations were chosen; CopperCore and APIS. The need for integrating these two components can be explained by the fact that QTI is a natural complement to LD. Furthermore, LD relies heavily on its e-learning services, which demand a similar integration.
Both CopperCore and APIS were independently developed as part of the JISC ELF and both are already being used by legacy systems. The latter introduced an additional requirement as the identified solution must deal with legacy systems for both services as well as clients. The switch to a new architecture should cause minimal intrusions in any existing code. Furthermore, the provided solution should be robust for new developments as the integrated services have their own development dynamics.
The CCSI architecture deals with these requirements by seamlessly inserting itself between the service and

client. By replicating the original API the consequences for the client are limited to a switch of services factory. The underlying services do not have to be changed at all. All inter-service issues are dealt with in the adapter and dispatcher. We have seen that there is an adapter for each service type and that an adapter has a contract enforced by an interface per service type. The latter concept makes the adapter robust for changes in the services; it makes it possible to completely switch service implementations with minimal consequences.

Finally, as highlighted above the CCSI architecture is not limited to the integration of CopperCore and APIS. Other services such as defined in the LD services part can and in fact have already been integrated in a very similar manner although the types of events are different. The work on CCSI will be taken up by the recently launched European Commission funded TEN-Competence [15] programme.

All code for CCSI is available as open source and may be downloaded from SourceForge at http://sf.net/projects/ccsi. For an easy up and running example of CCSI the CopperCore Runtime Environment, also known as CCRT, can be downloaded from http://coppercore.org. This runtime contains deployable versions of the CopperCore service, the APIS service and the CCSI integrative service. Additionally, the SLeD2 player downloaded from http://sourceforge.net/projects/ldplayer. Finally, the example UOL can be downloaded from http://dspace.ou.nl/handle/1820/555.

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The 8 Learning Events Model: a Pedagogic Conceptual Tool Supporting Diversification of Learning Methods

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Abstract

This paper presents the 8 Learning Events Model (8LEM), a pedagogical reference framework which was used, in more than 100 online course, as a starting point for instructional planning. Besides supporting teachers in early stages of the learning design continuum, the paper shows how this learning/teaching model, as a professional development tool, prompts them to diversify the learning methods experienced by students in their courses. A two-pronged rationale about the importance of this diversification with respect to "mathetic" competence development and epistemology is also proposed to discussion.

Keywords: mathetical competences, learning methods, teacher's professional development.

1. Introduction

Any teacher or instructional designer, who ponders over the best way to (re-)design a Unit of Learning (UoL), personalized or not, is confronted to a very wide range of possibilities. Quite soon, he/she will feel the need for a handy and ready-to-use model helping him/her to interpret the reality, to reduce its complexity, to guide choices and actions, to rely on a communicable reference vocabulary, to allow him/her safely moving further toward finer-grained concerns. Founding one's work on such a reference model is what separates the experienced practitioner from the novice one, what makes the difference between "learning/teaching recipes" and informed practice. Recently, authors working in the realm of instructional design construction [1] and personalized course delivery [2] drew attention on the danger lying in a pedagogically unframed development of learning objects, recommending therefore an up front adoption of some of the existing instructional events models. Working with a model allows also making the instructional design and its rationale "explicit" [3] or "transparent" [4] to the user, helping to defuse the "neutrality" usually professed by providers of e-Learning systems and standards [5, 6, 7].

The 8 Learning Events Model (8LEM) is one of the available models. Created by Leclercq and Poumay [8], it is extensively used by Labset (Support Lab for Telematic Learning), a 30 people research unit of the University of Liège, Belgium, for helping professors and trainers from public and private organizations design and develop their own courses and activities on the Internet. (The website http://www.elearning.ulg.ac.be, section "demos 02-05", provides – only in French - examples of the use of 8LEM in the shaping of 24 online courses). In the first section, we concentrate on the main features of the model and its location on a "learning design continuum". In the second section, we describe the practical way it is used with academy, especially for inviting them to vary the learning/teaching paradigms in the shaping of online activities (and possibly pedagogical patterns [9]) they design. The last section advocates for a renewed attention to this diversification issue, considering its relationship to mathetical competence development and epistemology.

2. The 8 Learning Events Model

2.1. Features of the model

The "8 Learning events model" introduces standardization of basic teaching and learning activities. It is composed of 8 documented teaching/learning events, i.e. ways of learning. This high level tool-kit provides guiding principle for taking decisions about how to divide the continuum of pedagogic practice into pedagogically meaningful parts. The 8 events are basic activity types (see figure 1) which can be applied in any context wherein activity structures' analysis and building are at stake.

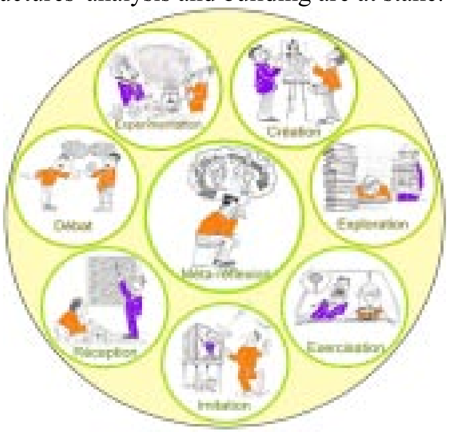

Fig. 1 - The 8LEM is a catalogue of 8 Learning Events describing the multiplicity of learning/teaching experiences

The 8LEM is a learning/teaching model, thus tackling both the learner and the teacher at the same time. It connects in a systematic way both the student's demand and the teacher's supply, and their interrelations (see figure 2). Learner and teacher's actions are complementary and interdependent, just as the two faces of a bivalve shell (such as a mussel or an oyster): observation/modeling, reception/transmission, exploration/documentation, self-reflection/co-reflection, debate/animation, creation/, creation/confortation, experimentation/reactivity, exercising/guidance. Providing an operational entry to learning, the model focuses mainly on cognitive aspects when considering the learner. (As such, it, at first glance, reflects the "acquisition metaphor of learning". But, when considered as a teacher's professional development, the model, as a artifact/process of pedagogical inquiry for practitioners, seems to have some features common with the "knowledge creation metaphor" [10]).

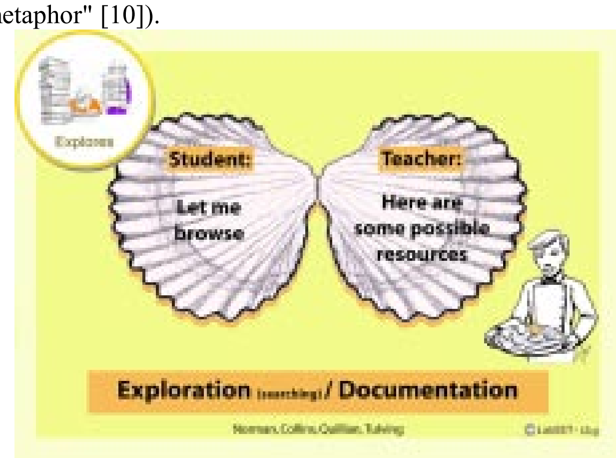

Fig. 2 - Example of mutual dependencies of learner's needs and teacher's supplies for the "Exploration" learning event

Other features of the model include a firm root in pedagogical theories, a concept-domain neutrality and cognitive facilitators (number of components kept in the limits of human capabilities [11], vocabulary located at an appropriate level of conversation [12]) for understanding and retention by practitioners. Incidentally, the use of 8LEM can also end up in a still rough but complete graphical design of learning flow (see figure 3), expressed in terms of learning experience types a learner is invited to traverse. Helping practitioners getting a quick grasp of what a UoL is becoming an issue of its own [13, 14, 15].

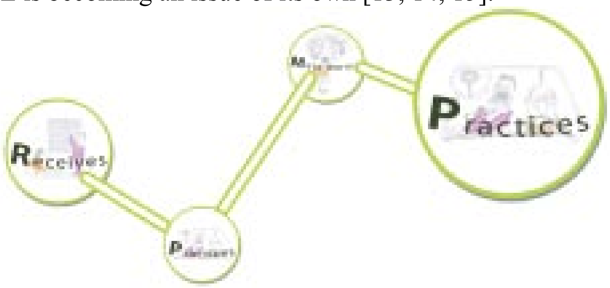

Fig. 3 - The 8 LEM allows for an understandable and systematic structuring and representation of UoLs

2.2. Location of the model

LabSET's work demonstrates that before having a UoL working online, teachers and trainers go down a path of progressive refinements, which we call, after Casey [16] a "learning design continuum" (see also Pernin [17]). Burgos [18] has a similar approach when he suggests a comparison between making an UOL and making a movie (see figure 4). In both cases, the path starts from rough descriptions and goes up to formal, machine-readable, designs. At each step, teachers need specific guidance, conceptual and technical tools.

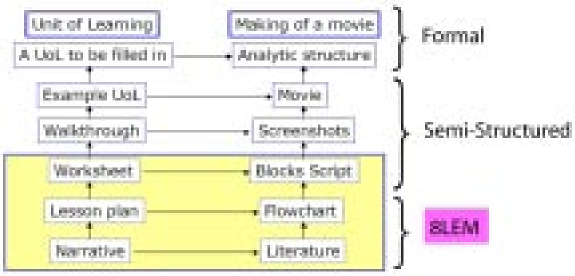

Fig. 4 – Teachers benefit from the 8LEM in early stages of the learning design continuum

As a clarifying framework of the design elaboration process, the 8LEM will prove mostly useful during an analysis phase completed by speaking with stakeholders and using generally free textual descriptions and paper-based documents. This stage of the instructional design process is the time during which major learning methods orientations must be chosen regardless the detail of their future implementation. This instructional planning, affording a low degree of formalisation of designs, deals with the "how to learn/teach?" issue. As Griffiths [13] notes: "At the UNFOLD Community of practice meeting in September a number of teachers and learning providers voiced their opinion that a methodology (or, more probably, methodologies) would be required for the first stage of analysis and the creation of the didactical scenario". Casey [16] expresses similar concerns about high-level of expression for UoLs: "(…) we need to also recognize the rougher and more tentative conceptions of pedagogy that practitioners really use". 8LEM is one possible support tool for this early phase of the instructional design process. Related to the IMS-LD, for example, it sets the stage for subsequent formalization, helping to link first teacher's reflection about what their future course will be to the official starting point of the methodology: the UML activity diagram [19, 20].

3. Descriptive/prescriptive use of the model

8LEM provides teachers with two types of help, descriptive and prescriptive. As a descriptive aid, the model is used to analyze an existing training strategy/teaching sequence. Its controlled vocabulary makes easier the identification of complex scenarios' elements. As a prescriptive aid, the model provides the framework for the creation of a new training sequence or for the enhancement of existing ones. So doing, it also acts as a support to educational creativity. The 8 learning events represent both a common ground and an exploratory territory for teachers. On the one hand, teachers have already experienced some of the events composing it. On the other hand, by bearing in mind a comprehensive model, teachers are invited to commit to new approaches of learning/teaching. 8LEM is intended to facilitate an improvement of rigor and at the same time to trigger pedagogical creativity.

Fig.5 - 8LEM is used in a descriptive/diagnostic function (the stethoscope's metaphor) or as an incentive for pedagogic creativity and diversification (the palette's metaphor)

4. Rationale for the variation of learning experiences

Although each learning event may fruitfully be used independently of the others, the model encourages the diversification of learning/teaching practice, by virtue of its own characteristics (restriction of number of events to eight, vocabulary pitched at the instructor's level, descriptive/creative modes). One of its underpinning principle is that variety benefits not only to current learning activities but also trains students to learning to learn. Should this assumption be confirmed, the diversity of learning experiences by which the learner is encouraged to learn would emerge as a criterion of educational quality. But why to vary? The model puts forward a number of reasons.

4.1. Diversification and mathetical polyvalence

Coined by Gilbert [21], the term Mathetics comes from the ancient Greek verb "manthanô", namely "to learn". It is further elaborated by Papert [22] who equates it to the "art of learning" and argues that "the kind of knowledge children most need is the knowledge that will help them get more knowledge" (p. 139). Alava [23] proposes a more comprehensive definition of mathetics: "To study mathetics is to study the whole of the procedures and social, cognitive and informational strategies used by the student to learn". Leclercq [24] takes up the word "mathetics" and enriches it with the notion of "polyvalence" meaning that it is in the learner's interest to gain exposure to a whole range of learning modes in order to become a more competent learner, polyvalent in exploiting the variety of methods, resources, constraints, etc. This polyvalence becomes an even more urgent necessity in a "'knowledge society" as this experience of diversity prepares the learner to take advantage of any future learning occasion [25]. By being offered such a variety of methods, students will be supported in the development of their abilities for "learning to learn". Thus, regardless of subject matter, one of the preoccupations of teaching becomes to ensure that learners are confronted with a variety of methods, resources and constraints, some of which may be completely new to him or rarely practised. For Leclercq, to the learner's "mathetics polyvalence" corresponds the teacher's "didactic polyvalence", i.e. the capacity to organize diverse quality learning experiences. Facilitating the spring of "polyvalent learners", the 8LEM provides a tool empowering educators for offering their pupils a rich, i.e. multi-faceted, learning experience. (This concern with the diversity of learning experiences, incidentally, intersects with discussions on learning styles theories. An instructor aware of the heterogeneity of learning styles will organize educational sequences in such a way that they incorporate a certain degree of variety, in order to multiply his chances of "motivating" a wider spectrum of profiles).

4.2. – Diversification and epistemology

The advantage of covering a subject by means of varied events does not lie purely in the fact that it trains the learner in a variety of learning methods. It also has an impact on the content itself. Varying events also means, over and beyond the question of methods, constructing and enriching the concept and the conceptual network associated to it. A medical student will have a particular idea of the stomach if he reads (reception) documents about that organ. But he will perceive a different facet if he is invited to perform a free dissection of a stomach (exploration). His conceptual network will be enriched further if, as an observer, he attends a stomach operation (imitation). When he himself has practised stomach operations (drilling), his conception of the stomach will have evolved still further. Finally, when he engages in discussion with his peers (debate), his conceptual network will expand even further. As well as experiencing various learning methods, he will in so doing have developed a multimodal approach to the concept in question. In this respect, the model is consistent with a general claim made by educational psychology (Paivio, Miller, Gartner and others) that the deployment of multiple learning channels reinforces learning. Although, the 8LEM remains primarily focused on learning methods, it does have a secondary impact on the contents of learning. Moss [26] provides an example strikingly similar to the previous one coming from veterinarian field: "We could learn a great deal more about dogs if we worked with dogs of different breeds, ages, and temperaments than if we only worked with only one dog. To extend that example, we could learn even more about dogs if we worked with a variety of them across settings - in the city, in the country, when other people were present, when other dogs were present, and when other animals, like cats and birds, were present. But those are just some of the contexts that would influence and expand our learning about dogs. What if we had a group of dog experts with whom we could discuss our understandings as we were learning? What if we could post to a bulletin board to discuss our observation that the Cairn Terrier has an extremely loud bark? Would the discussions that ensued influence our understanding? What if we were able to talk with someone privately through e-mail to discuss concepts that we did not understand or that we would like to clarify? Learning about dogs in a variety of contexts would extend the chances that we could apply what we learned about dogs to new contexts. In other words, the ability to apply newly constructed knowledge in new circumstances depends in part on the variety of circumstances in which we have learned or practiced the information or skill". A "multimodal approach to concepts" might provide an overarching principle for the organisation of diverse learning. Noss [27] and Polhemus [28] seemingly convergent concerns with this issue of mathetics/didactics multi-faceted diversification.

5. Conclusion

The design of an online course is a unique opportunity for staff development [16]. The model presented guides teachers and learners to diversify learning and teaching with regard to pedagogical approaches. It motivates learners and teachers to reflect the design of courses as well as learning, and teaching itself. The 8LEM acts here as a lever leading teachers to start reflecting about their current courses instead of "just making a course". Progress in professional practice is achieved by inviting educators to articulate their current practice and, possibly, to innovate by extending their teaching/learning methods repertoire. Subject to this second challenge, the 8 LEM stresses the value of ensuring a good balance between learning modes, taking for granted that an educational activity ought to take into account products and processes. The practical realization of this educational ideal – a diversified panel of learning experiences offered to students – probably entails extra reflection from the very start of the learning design continuum. In this paper, the mathetical and epistemological benefit of this diversification is promoted within an intra-individual perspective. But as the multimodal approach of concepts entails in any cases the design and the delivery of a variety of learning experiences organized around learning objectives, future research will focus on the extent to which assets produced for serving this approach might also be re-used within a personalized instruction context which drives similar attention to diversification.

6. Acknowledgement

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Representing adaptive eLearning strategies in IMS Learning Design

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Abstract

For almost three decades the concept of adaptation of computer education has been an important topic. Approaches to giving the student a central role in his/her own learning process have been described in literature from early Computer Based Training systems to more recent Adaptive Learning Hypermedia Systems. However, the approaches have tended to be highly specific in their implementation, hampering comparison and extension of results in the field.

The IMS Learning Design specification (IMS LD) addresses many requirements for computer based adaptation and personalized eLearning.

In this paper we give an overview of a number of approaches, definitions and features of adaptive learning; in the second section we identify how adaptive features and elements can be addressed by IMS LD, detailing a number of example Units of Learning which illustrate adaptation in different ways. In the final section we discuss issues in attaining the right balance between effort invested and results acquired while modelling IMS LD adaptive Units of Learning.

Keywords

Adaptive learning, adaptability, personalized learning, IMS Learning Design

1. Introduction

There are many definitions of adaptation in eLearning systems [1]. Usually the concept is focused on the student, although adaptation involving tutors is clearly also possible. From the user interface to the eLearning resources to the process there are many aspects to take into consideration. In this section we show and briefly analyze several approaches to this issue.

From the early eighties, where Computer Based Training was used to fully control the flow of a learning process [2, 3], to the concept of Adaptive Guidance, which provides rich information and a diagnosis to help the learner to take effective decisions about his own learning [4], there is a wide collection of approaches. For instance, to incorporate the tutor as a key factor in the adaptation process [5], or to build a blended system strongly supported by AI agents [6]. All are based on the proposal of personalized learning adaptation to the context of each student to stimulate his learning process and to encourage his involvement in this process [7-9] These approaches also hold that the largest benefit comes from personalized instruction [10]. This does not necessarily imply that a user/student should keep full control over his training, because this would mean that 1) the student knows what is the best for him along a learning script; 2) the student is aware, knows and controls all the contributions that he can make to his own process; and 3) the student is able to carry out the right decision when all this information is collected [11].

We define adaptive eLearning as a method to create a learning experience to the student, but also to the tutor, based on the configuration of a set of elements in a specific period aiming to increase of the performance of a pre-defined criteria [5]. These criteria could be educational, economic, time-based, user satisfaction-based or any other involved in eLearning. Elements to modify/adapt could be based on content, time, order, assessment, interface and *etcetera*.

In modern learning theory there are four main approaches to adaptive learning [12, 13]:

- *macro-adaptive*, selecting a few components that define the general guidelines for the eLearning process, such as learning goals or levels of detail and mainly based on the student's profile;
- *aptitude-treatment interaction*, proposing different types of instructions and/or different types of media for different students;
- *micro-adaptive*, monitoring the learning behavior of the student while running specific tasks and adapting the instructional design afterwards, based on quantitative information;
- *constructivist-collaborative*, focused on how the student actually learns while sharing knowledge and activities with others.

A modern system based on adaptation should consider all of them to provide a wide range of possibilities on eLearning.

2. Types of adaptation

Taking as a start that neither books nor computers guarantee that a student actually learns [14], a combination of the following proposals on adaptation could support the performance of every role in a learning process [7, 15].

Traditionally, three types of adaptation have been proposed:

1. *Interface-based* (also called adaptive navigation and related to usability and adaptability) where elements and options of the interface, are positioned on the screen and their properties are defined (color, size, shadow, etc) [16]; this is closely related to general customization and for people with special needs which influence personalization, such as color blindness or poor hearing, for instance [17].
2. *learning flow-based*, where the learning process is dynamically adapted to explain the contents of the course in different ways;
3. *content-based*, where resources and activities dynamically change their actual content, as in Adaptive and Intelligent Web-Based Educational Systems based on adaptive presentation [18, 19]

Additional kinds of adaptation are [20]:

4. *interactive problem solving support*, that guides the user about the next step to take in order to get the right solution of a problem;
5. *adaptive information filtering*, taking care of an appropriate information retrieval that provides only relevant and categorized outputs to the user [21];
6. *adaptive user grouping*, that allows *ad hoc* creation of groups of users and collaborative support on carrying out specific tasks.

Last, we should extend the two lists aforementioned with:

7. *adaptive evaluation*, where the evaluation model, the actual content and the running of the test can change depending on the performance of the student and the guide of the tutor [5];
8. *changes on-the-fly*, the possibility to modify/adapt a course on-the-fly by a tutor or author in run-time [22], moving beyond the previous types which are set-up and defined in design-time [23, 24].

Out of a study based on literature, in this report we see up to eight different kinds of adaptation being carried out in eLearning systems. All of them use various inputs provided during the learning process and aim to tune the activities and actions of the learner to get the best learning experience as possible [25]. A wide and strong set of rules of dependencies among users, methods and learning objects is needed to describe these eight types of adaptation, and moreover their possible combinations [26].

3. IMS Learning and adaptation

IMS LD [27] provides a modelling language able to design and run Units of Learning (UoLs) [28-30]. There are two main approaches to create these UoLs: a) An initial analysis [10] takes the

adaptation fully modelled inside a Unit of Learning, without an external link, as an autonomous entity, and describes four areas in IMS LD where some kind of adaptation could take place: *environment, method, roles* and *activities*. The scope of the paper is mainly focused on a number of possible modifications in three of them: *environment, activities* and *method*. Management of roles is out of our scope, although section 2.6 points it out briefly; b) Van Rosmalen and Boticario [22] additionally address on the external adaptation of a UoL, making modifications to both the internal elements of the UoL and the orchestrating layer through which the UoL is delivered, i.e., a player of UoLs.
We now examine how IMS LD can be used to represent each of the eight types of adaptation aforementioned.

3.1 . Interface based

This issue relates to the user interface provided with IMS LD players such as the player included with *CopperCore* [31], the *Reload Player* [32] and *Sled* [33]. The current generation of these tools do not provide facilities to allow interface adaptation in run-time, although *Sled* can be customized during the set-up.

3.2 . Learning flow based

The description of an adaptive learning flow is mainly based on four different elements of IMS LD, available at Level B [30, 34]: *properties, calculations, global elements* and *conditions*. In addition, monitoring services can be added to track users' behaviour and adapt the flow dynamically. An example of these features is provided by *Learning to Listen to Jazz* (all the examples can be found at [35]). A student can learn something about four different Jazz styles in a sequential way, and he can choose between a thematic itinerary and a historical itinerary, following different milestones in the course. An additional example is *GeoQuiz 3* where the activities are defined by the performance of a student after answering an evaluation form. Depending on the final score and the related level acquired, one or another activity is shown. A final example is *Cándidas II* showing full learner control by the student, who directly selects which is the best method to study a lesson among four different options.

3.3 . Content based

The content of an activity needs a resource linked to the element Activity Description. Although this link cannot be changed at run-time, three other elements can be modified dynamically:

- the content inside an XHTML resource, defining classes and DIV layers that can be hidden and shown based on certain parameters;
- the content of pre-defined properties/variables, that can be replaced with other content typed-in on the fly;
- the content of an activity can be adapted switching showing or hiding one of several linked environments.

Two examples of the use of environments are *Learning Activities with Conditions*, where a student decides the granularity level that he wants and *From Lesson Plan to LD Level B,* where again a student takes control and switches on and off the audio support of the UoL. Finally, *Learning to Listen to Jazz* provides contents linked to several Activity Descriptions and related environments, progress-based.
An additional way of content-based adaptation is the modification of contents linked to fixed resources and based on external tools. For instance, a resource linked to a wiki service hosted outside an IMS LD UoL could adapt its content dynamically, based on users', tutors' or authors' actions.

3.4 . Interactive problem solving support

This kind of adaptation could be considered as an extension of *learning flow based*, with the appropriate definition of properties and conditions modelling the itinerary, and the incorporation of a monitoring service allowing the tracking of the learning process of the student, making *ad hoc* remarks and changing the process as needed. These changes can be carried out 1) by modifying specific arguments by the tutor, 2) by the execution of specific design-time rules, or 3) by a combination of both mechanisms. An example is *What is Greatness* where the tutor moderates the contributions of a group of students on an open question, providing access to the next step when the tutor thinks that the current one is finished. A further example is *Free Style Assessment* where a tutor and a student carry out a commented open evaluation of an assessment. The tutor is entitled to close and block every step and to provide contextual feedback.

3.5 . Adaptive information filtering

IMS LD is not designed to provide adaptive information retrieval. Some rudimentary facilities are available through the *index-search service*. More practically, IMS LD could point out to an external searching service providing the container for the run of this application and also for the visualization of the results.

3.6 . Adaptive user grouping

User management has two approaches, one based on roles' creation and one based on users' creation. Using the management system provided by several tools and engines – Coppercore, Reload, CopperAuthor [36] – once the UoL is published, the administrator (maybe the teacher himself) can add and delete users and assign them to a specific run of that UoL. This means a *de facto* group [37]. However, the dynamic creation of roles after the publishing process is not currently possible. Once a definition of roles or stakeholders is available, and a run of a UoL is defined, specific users can be added to, or removed from, any of these groups and they can be played in a run. Some representational facilities are available in IMS LD to support creation of groups (min-persons and max-persons) and although assignment of users to groups can be achieved, fully automatic on-the-fly creation of groups may require additional representational devices.

3.7 . Adaptive evaluation

Taking the performance of a student in a Unit of Learning as input, a full set of parameters can be stored in local properties to be used in the adaptation of formative or summative evaluations. As we have already explained related to *Geo Quiz 3*, certain actions and answers of a user can be allocated into variables pre-defined in design-time and they can also be interpreted in run-time following a set of rules. In this way, both the evaluation system and the content itself, and even the interpretation of the results, can change for each user. An example is *Quo Builder 2* where a questionnaire can be fully set-up with questions, answers, thresholds and feedback being defined in run-time. Again, the main obstacle to overcome is the run-time modification of the skeleton itself, such as the ordering, grouping and numbering of questions and answers. However we can define a wide set of questions that can also be hidden and shown on demand, providing a top-down 'simulation' of adaptive extensibility.

3.8 . Changes on-the-fly

Every UoL has three clearly different steps in its own life-cycle: design-time, publishing-time and run-time [28]. Once a UoL is published it is not possible to change structure, method or definition of basic parameters (such as conditions or properties, for instance). Of course, if a UoL is so designed, a tutor is able to change the way a student perceives the course and the flow: 1) tutors can update the content, based on pre-defined content or on new contributions; and 2) tutor can also influence the learning itinerary, uploaded files, shown and hidden content elements and structure elements, etc This means that a tutor is able to change things on the run, as long as he had previously defined that possibility in design-time. This solution comes with a high expense on implementation and support, though. An example is the already mentioned *Quo Builder 2* where a tutor makes the set-up and initialization of an evaluation form within run-time, that is subsequently filled by students.

4. Discussion

IMS LD can be used to represent a wide-variety of approaches to adaptivity in eLearning. Using the specification as a language into which adaptation strategies could be exported would allow for comparison of approaches adopted by different research groups. Furthermore, support for the importing of adaptive Units of Learning into adaptive engines would allow additional application of adaptive approaches, helping to reveal any implicit assumptions and promote a shared understanding of the what, why and how of adaptive eLearning. Using IMS LD in this way would also force a debate on the use of standards for the representation of the information upon which adaptation occurs (eg [38])

The possibilities for adaptation supported by IMS LD are diverse. From the eight types of adaptation described we identify three levels of support: a) *Learning flow*, *content*, *evaluation* and *interactive problem solving support* are well supported; b) *User grouping* and *full modification of a course on-the-fly* are partially supported, leaving out of IMS LD some features; c) Last, as some pending issues with no support at all are *dynamic modification of learning structure and method in run-time*, and *adaptive information filtering and retrieval*.

Nevertheless, with several types of adaptation, like *content* and *information retrieval*, some walkaround is also possible to provide a specific support on adaptation, i.e. linking an activity to an external tool providing a related service and keeping IMS LD as a container for external adaptation. In conclusion, with the appropriate support, IMS LD can build adaptive and rather flexible learning experiences for every stakeholder.

The current state of the art in IMS LD editors, such as *CopperAuthor* and the *Reload Editor*, makes the creation of adaptive UoLs technically possible, but the process is a complex one. A learning designer is required to know the technical editors in depth and to have intimate knowledge of the specification. Currently, this means that a significant effort is needed to create adaptive UoLs in IMS LD editors. However, the use of IMS LD as an inter-lingua for existing tools from the Adaptive Hypermedia arena seems a promising line of investigation.

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Seamless production of interoperable e-Learning units: stakes and pitfalls

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Abstract. The modeling of a 28-week course in Information Theory using IMS Learning Design Level B specification proved its efficiency for describing complex learning scenarios. This article briefly summarizes the method used to create the real-life unit of learning. The experiment showed that, although various types of editing software and rendering engines are available, the resulting production process relies too much on computer specialists to be adopted as a strategy at the institutional level, and that the lack of integration exhibited by both the software and the engines in terms of Virtual Learning Environments prevents large-scale deployment.

Keywords: learning scenario, interoperability, IMS Learning Design

Introduction

The Swiss Virtual Campus is a national initiative for the promotion of eLearning in Higher Education. It provides funding to multi-partner teaching projects and technical infrastructure such as a secure authentication system for all Swiss university students and access to a commercial Virtual Learning Environment (VLE). Therefore, the question of the reusability and interoperability of the learning material was not, at first, perceived as a major issue. However, the scope and complexity of the courses made it impossible to rely on a unique product, and brought to light the necessity of elaborating strategies for later redeployment of both content and learning scenarios.

As far as content is concerned, IMS Content Packaging or SCORM compliant VLEs provide basic export/import tools that allow a relatively easy redeployment. Learning scenarios, which convey the teachers' personal views and expertise, are, on the contrary, stuck in the tool where they were initially developed. Pedagogically speaking, learning scenarios are indispensably beneficial, but they cannot conceivably be manually rewritten in case of a VLE change. Therefore, the publication of the IMS Learning Design (hereafter, "IMS-LD") specification seemed to be a good omen.

The experiences and points of view presented here are those of a center that provides pedagogical support to the teaching staff. Its main duties are non-technical. Designing learning activities and scenarios is a core practice, with or without the support of technology, and the involvement of coding specialists to ensure their sustainability cannot be regarded as a viable possibility. We definitively needed to establish a design and production process that integrates the issue of reusability and interoperability of learning scenarios from the very start and – unlike the industrial approach adopted by large institutes for distance education [1] – which relies on generic computer skills. We decided to experiment on the potentials and shortcomings of the methodology proposed by IMS. Even though we were aware that no compliant VLE was available, we hoped – and still hold the view – that the next generation of authoring and teaching tools would provide us with a suitable long-term solution.

The work presented here uses the IMS Learning Design version 1.0 technical specification to create a rich learning unit. The latter can account for all aspects of the learning scenario, allowing the rendering of the finest interactions between all actors, thus providing the largest possible didactic liberty to the teachers and developers [2] [3]. The following text aims at detailing each step that is needed to translate a real-life academic course into an interoperable learning unit; it also will provide a walkthrough that will point out the difficulties arising from the process, showing why the seamless production of such learning units is not yet at hand.

Approach

The approach used to design the learning unit presented here was a three-step process involving three different people. To fulfill our expectations, this process should, however, involve two, or even one single step, performed by the teacher him or herself. Firstly, discussions took place between the teacher and a learning engineer in order to create a model of the course. When a common agreement had been reached, an UML-like activity-diagram of the course scenario was made, taking into consideration all roles involved in the learning/teaching process, mapping activities related to them, and showing links between activities. In a subsequent step, the concepts of the UML diagram were translated into a learning unit (an IMS-LD compliant file) using various software applications and some manual coding. The next parts of this section describe these steps in more detail, and signal the places where simplifying the process would be a decisive advantage.

Course Description

The course being modeled is an online course in Information Theory targeted at:

- students of geography, linguistics, and statistics;
- Bachelor- and Masters-level computer scientists, more familiar with mathematics, and focusing on general knowledge and applications of the theory.

The course is composed of ten modules, each consisting of different Information Theory topics (core modules: general definitions and major theorems, and specialized modules: applications to geography, linguistics, statistics, and informatics). Each module includes three levels of difficulty and mathematical abstraction: general knowledge (level 1), main results with only simple proofs (level 2), and all results with complete proofs (level 3). One given implementation of the course is then built by combining different modules at different levels. For instance, the course focusing on linguists includes all common modules at level 1, and the linguistics module at level 1; the bachelor level course for computer scientists includes all common modules and all informatics modules at level 2. Similarly, a course for mathematicians would include all common modules and the statistics module at level 3.

During the first semester, students are required to study the fundamentals of Information Theory on their own, and must, in addition, explore its possible applications in their specialized fields of study.

They are, therefore, provided with:

- a limited number of introductory or synthesis recorded videoconferences;
- the text of the relevant modules;
- concept maps which help the visualization of the organization and content, and revisions of important definitions;
- sets of control questions to verify their levels of understanding;
- various animated and interactive examples in terms of demonstrations;
- problems and exercises, with solutions;
- the help of one or more online tutor and of the professor, via forums.

During this first semester, the communication tools are mainly used to collect and answer students' questions. Each computer scientist and engineer is then required to take an exam, while human sciences students begin a second semester, in which these tools are used to assist them in their personal work, allowing them to share knowledge and to monitor attendance.

The second semester is devoted to personal work based either on an individual or a group project, or on a study program leading to a traditional oral or written exam. Students use the VLE to deposit successive versions of their work, which can be examined by the whole group, and to inform the teacher of their progress. Individualized exam "contracts" are elaborated and negotiated online, using a learning journal as an asynchronous communication tool.

Pedagogical Modeling

According to the IMS methodology, pedagogical modeling should begin with the creation of a textual and visual representation of the course. [4]. Since no UML editor can generate automatically an IMS-LD compliant XML file, the modeling of the 28 weeks of teaching and learning activities had to be divided in two separate operations. The activity diagram was designed as a visual representation of the roles, activities, decision points, and timeline of the course.

Although necessary to obtain a full picture of the sequence of activities, this step is only a preliminary modeling of the teaching and learning activities. In an ideal world, this would not be an isolated operation, and would provide the modeler with a skeleton of the actual course in an IMS-LD compliant format, to which the learning environment, as well as the variables and conditions, could easily be added. MOTplus [5], although not an UML editor, heads in this direction and allows the generation of IMS-LD level A-compliant XML files. However, the modeling of a complex sequence of activities with this tool remains a task that is too disconnected from the daily practice of the average teacher, if only because the modeler needs to master the rules and constraints used for pedagogical modeling in the software, and a fair knowledge of the specification itself.

Learning Unit Design and Conception

Once the UML diagram of the pedagogical process had been established, the learning unit itself had to be created. This was achieved mainly by using the Reload Learning Design Editor software, which provides a comprehensive and intuitive graphical UI, allowing the creation of a learning unit complying with the Learning Design specification [6]. Some additional coding (i.e. the writing of XHTML files providing two-way interaction between the end-user and the learning scenario), however, needed to be done from scratch.

The learning unit that had been produced consists of a ZIP package containing an XML manifest file and all files needed to render the course properly: instructions, content, etc. The learning unit produced adopts the level B of the IMS-LD specification; this means that, for scenario flexibility purposes, the use of variables and of conditional events is possible.

The Reload Learning Design Editor allows the user to build a course scenario based on the IMS-LD concepts. These concepts include an approach based on roles and activities; each participant, being related to a role (i.e. teacher, tutor, student, etc.), performs a particular activity that is based on his or her role and personal preferences. Such activities can then be associated with various environments, which can provide facilities such as communication tools (e-mail, discussion forums, and so on), tracking and indexing functions, or simply the means to supply the user with additional content.

Building a course scenario based on these concepts (roles, activities, variables, conditional events) from an UML workflow diagram first requires identifying roles and activities: this is the easy part. The next step demands some reformulation, as a description of the various relations between the different roles and activities is needed. This reformulation consists mainly of converting human semantics into the limited number of concepts available from the IMS-LD specification.

The IMS-LD specification uses roles and activities to define role-parts, which are the building blocks of the learning scenario: each role-part associates one role to one activity. Several of these role-parts can then be grouped into acts: an act is a set of role-parts that takes place (that is, begins and ends) at the same time for all actors of the scenario, thus providing synchronization abilities. In the unit developed here, one act groups all activities of one academic semester (which, of course, takes place at the same time for everyone), while some other synchronization features are achieved using variables and conditions. It is indeed possible to use conditions on the values of variables to make visible or invisible elements of the learning scenario, such as tools, content, or activities.

Firstly, all activities are built; each one is then mapped to one role, thus defining role-parts. The use of conditions allows making various elements visible or invisible depending on any constraint. Furthermore, the use of variables allows the precise tracking of students by the monitoring of their variables, which for instance may keep track of how (or if) some activity has been performed or of their learning preferences. To allow the setting and visualization of variables by users playing the learning scenario, XHTML files have to be written from scratch.

At this stage, the most arduous task is that of the learning designer first having to write down the complete learning scenario, intertwined with all of the variables and effects of the various conditions (i.e. availability of the various activities). Writing the IMS Learning Design itself becomes possible only once this work has been accomplished. It is, thus, very difficult to make even small modifications afterwards, such as adding or removing an activity. Besides, one thing was found to be missing from the IMS-LD specification: the ability to form groups of learners. Grouping learners in order to facilitate active learning, (e.g. problem-based or project-based) is, indeed a common practice, and the impossibility to describe such interactions in an easy way with the specification is, in one sense, a shortcoming which should be tackled.

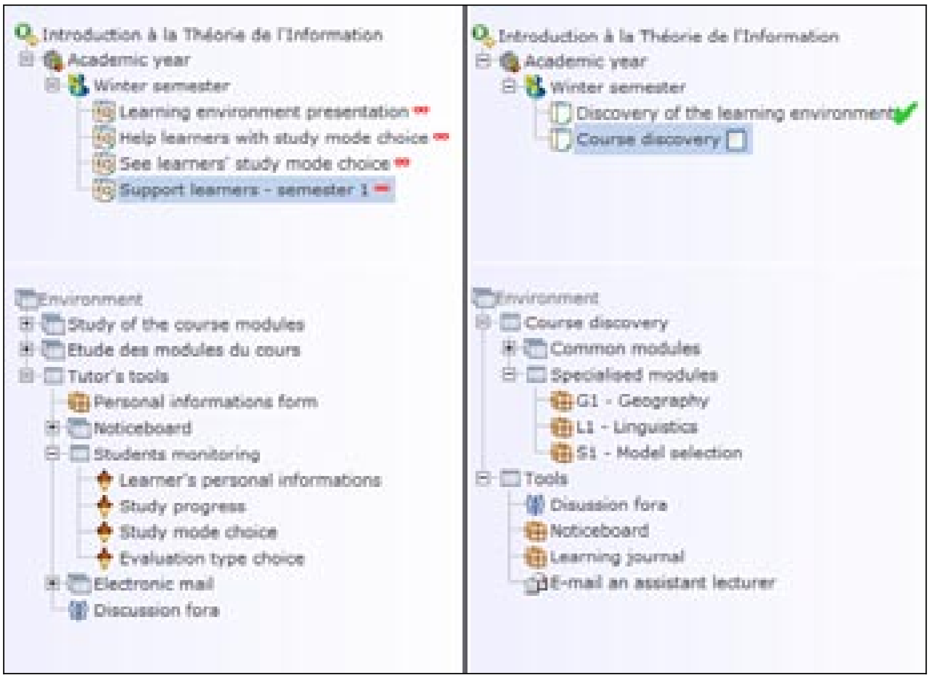

Fig. 1. Different activities and environments are presented to actors of different roles. On the left side are shown the activities and corresponding environments which are presented, at some point of the scenario, to a tutor, allowing him or her to see, among other things, the various students' choices made so far. On the right side of the figure are shown the activities available at the same time to a student.

Running the Learning Unit

In our institutional context, the primary purpose of modeling units of learning would be to ensure their portability from one VLE to the other. Although sharing learning objects and scenarios in repositories might be an additional incentive, our main worry is the issue of durability, and this is where the experiment turns out to be inconclusive. Getting the learning unit running necessitates an IMS Learning Design rendering engine, as, at this moment, no course management system allows the importation of such a unit. The CopperCore engine [7] was chosen to test the produced learning unit because it was able to render most elements of the learning scenario. It, however, provides only a basic rendering layer; it was, indeed, not aimed at providing a virtual learning environment, but a low-level Learning Design engine (which could be incorporated into a real learning environment).

The first step to get the learning scenario running is, then, the instantiation step. That is, one needs to map actual users to the roles of the scenario, thus creating one scenario instance. Users have to be manually added to the different learning scenario roles, which, again, can be quite a hassle, as this has to be done within a command line interface. Once all needed users have been added, the CopperCore engine allows users to run the learning scenario. Fig. 1 shows the various activities proposed at the same moment to two different actors having different roles within the learning unit.

A need for integration

In our real-life settings, both the production and use of the learning unit would, however, have to be different to be accepted as a viable strategy. Going through all of the following steps writing a UML diagram of the learning scenario to identify the needed roles and activities

- writing down the whole IMS Learning Design in order to correctly use the variables and conditional events
- writing the IMS-LD compliant files with Reload Learning Design Editor (some of them, from scratch)
- rendering the learning scenario with the CopperCore engine

is certainly suitable for learning and testing the specification itself.[1] Except for a small number of projects, the courses would have to be designed and produced by the professors or their teaching assistants. Therefore, the generation of IMS-LD files should be embedded into simple design tools, preferably within the VLE, in a way similar to that implemented in LAMS (Learning Activities Management System) [8].Although not based on IMS-LD, LAMS illustrates a concept that might bridge the gap in a context where teachers are the main producers of technology-enhanced courses. While the framework, tools and sequencing of the course is provided by the VLE,[2] the teacher models one learning activity after the other, dragging icons representing the tools that are needed to proceed with the activity on a design screen where instructions, resources and conditions can be added in a very natural way[3]. The relevant product would be an IMS-LD compliant VLE with learning activities design functionalities. Those would provide visual and intuitive means to create sets of instructions linked to the relevant resources and tools, and be able to automate the generation of the XML files needed to redeploy the course in another compliant VLE. Specialized help could, thus, be restricted to a few highly sophisticated courses and the specification be adopted on a large scale.

Conclusion

At the University of Lausanne, the production of technology-enhanced courses is done mainly by the teachers themselves. Therefore, the issues of sustainability and interoperability of the learning scenarios, although fully appreciated by the eLearning support staff, must be kept behind the scenes. Regular teaching staff members would very easily be discouraged by additional technical constraints imposed upon their work. In such an institutional context, the modeling of the Online Course in Information Theory according to the IMS Learning Design specification served two major objectives. The first was to test the adequacy of the specification to describe real-life courses that were not designed on purpose, and the second was to identify the conditions needed for the adoption of the specification to

[1] A method for a full evaluation benchmark of expressiveness and suitability of IMS-LD is proposed by Caeiro-Rodriguez et al [9]. The authors designed a comprehensive methodology based on pattern recognition.

[2] Moodle, Blackboard, Sakai and WebCT in a near future.

[3] For a technical discussion of LAMS and IMS-LD, see the article by Berggren et al [10].

ensure the portability of the online courses on a large scale.

The result of the experiment is promising, but it also clearly shows that the natural integration of the specification with actual practice is not yet at hand. Surely enough, IMS-LD proved adequate to successfully model the 28 weeks of learning activities and all the related tools and interactions. The complete process required a three-person team composed of a professor, a learning engineer, and a skilled computer staff member willing to dig into the specification, who produced the level B-compliant XML file using the Reload Learning Design Editor. The resulting learning unit can be run using a rendering engine such as CopperCore, with each role correctly performing the intended actions with the adequate tools.

However, although IMS-LD seems to provide a potential solution to a problem encountered by many Higher Education institutions, its practical use is hampered by a much too complex flow of production. The UML modeling and the translation of the activity diagram into the IMS-LD concepts of activities, activity-structures, and proprieties are out of reach of the typical staff in an educational context. Unless both the visual modeling of the learning activities and the generation of the compliant XML files can be integrated into the usual pedagogical design practice of the teachers, the large-scale use of the specification will remain an unviable option in our institution.

While assumedly a technical and commercial challenge, the missing integrating product can easily be described: an IMS-LD compliant Learning Management System that would provide the course framework and set of tools, equipped with a LAMS-like visual learning activities design tool which would allow the teacher to sequence simply activities and type in instructions and resources references. In addition, the VLE would be able to generate a proper IMS-LD file with all of the necessary resources and proprieties, ready for importation into any other compliant VLE. A natural and intuitive production process could then be implemented, ensuring that teachers' work and creativity are not at risk of being lost.

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From collaborative virtual research environment SOA to teaching and learning environment SOA

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This paper explores the extension of the CORE VRE SOA to a collaborative virtual teaching and learning environment (CVTLE) SOA. Key points are brought up to date from a number of projects researching and developing a CVTLE and its component services. Issues remain: there are few implementations of the key services needed to demonstrate the CVTLE concept; there are questions about the feasibility of such an enterprise; there are overlapping standards; questions about the source and use of user profile data remain difficult to answer; as does the issue of where and how to coordinate, control, and monitor such a teaching and learning system.

Keywords: collaborative, virtual, environment, teaching, learning, service-oriented

The Collaborative Orthopaedic Research Environment (CORE) is a Virtual Research Environment (VRE) project funded by the Joint Information Systems Committee (JISC) of the Higher Education Funding Council for England [1], [2]. This paper explores the possible extension of the CORE VRE to a full collaborative virtual teaching and learning environment (CVTLE) employing a service-oriented architecture (SOA), and considers some of the issues involved.

1 The CORE VRE project

The CORE VRE project has developed a Web service based demonstrator for supporting the collation and analysis of experimental results, the organisation of internal project discussions, and the production of appropriate outline documents depending upon the requirements of conferences and journals selected for dissemination. In the context of orthopaedics, experiments can be multi-centred clinical trials that involve analysis of large data sets, documentation needs to be written collaboratively, and experiments need to be managed and co-ordinated for geographically dispersed researchers.

The service-oriented architecture of the CORE is illustrated in Figure 1. The user accesses the virtual collaborative environment through a portal framework. Portlets within this framework provide for authentication, authorization, management of the user profile data, and workflow management of the experimental or research protocols and processes. From the portal framework, the user's needs for collaborative discussion, paper editing, data management and analysis, and GRID applications are provided by appropriate generic Web services.

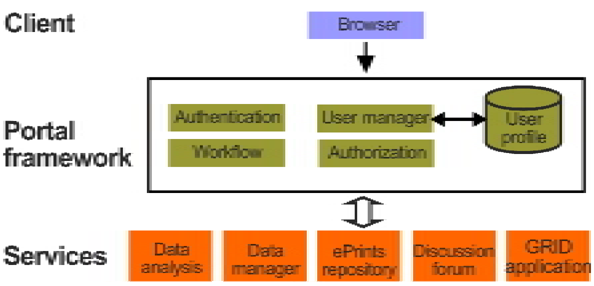

Figure 1: CORE architecture

CORE provides the basis for integrated computer support across both the research and educational domains, because these activities are intrinsically coupled as a part of the requirements of the orthopaedic surgeon's Continuing Professional Development.

2 From VRE to CVTLE

The extension of the CORE VRE SOA to a full collaborative virtual teaching and learning environment (CVTLE) is illustrated in Figure 2. We keep the terminology of 'portal framework' to describe the gateway interface between the student's client browser on the one hand and the various teaching and learning services which can be accessed on the other.

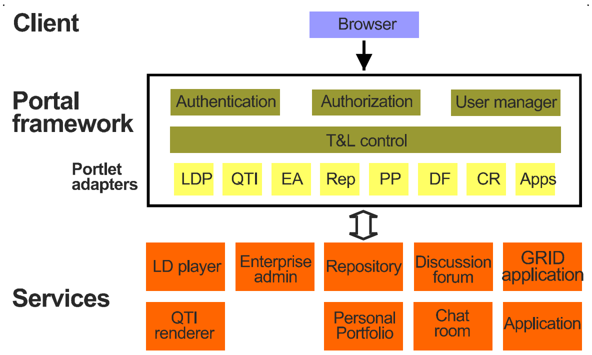

Figure 2: CVTLE architecture

The CVTLE architecture of Figure 2 illustrates the relative ease with which the services required by a teaching and learning application can in principle be added to a SOA. To the collaborative virtual research-oriented services of the CORE can be added teaching and learning-oriented services of questions, tests, and examinations (QTI renderer), collaborative lesson content sequencing (LD player), student's personal portfolio, chat room, and so on, resulting in the CVLTE.

The influential paper of Wilson *et al.* [3] discusses in detail the advantages of using service-oriented architectures. In this context the following particularly apply:

- Appropriate services can be used as required with new services being relatively easy to integrate.
- Third party services can easily be incorporated into the application as required.
- The relative ease with which services can be incorporated means there is less danger of technology 'lock in'.

In making these service additions, however, some issues arise, and it is the purpose of this paper to identify these issues and the need for research and development work to address them.

Existing learning environments such as Moodle, LAMS, Blackboard, and Sakai offer feature sets similar to the CVTLE of Figure 2, but they are not implemented as SOAs and do not adhere to any relevant standards for portals and portlets such as WSRP [4] and JSR168 [5]. Finally, in moving the CORE VRE to a generalised CVTLE, we find that each service requires an adapter [6] to support the communication between the Teaching and Learning control and the service involved. This point is elaborated in 3.6 below.

The presentation and discussion of this paper brings the key points up to date from a number of similar reviews, in particular that of Olivier [7] where the components of a CVTLE (called a learning design runtime architecture) are outlined and explored in detail.

3 Teaching & learning services

3.1 QTI renderer

The JISC-funded Assessment Provision through Interoperable Segments (APIS) project [8] has delivered open source code libraries for QTI v2.0 item rendering. R2Q2 [9] is a newly-started JISC-funded project to exploit and extend the APIS material and provide QTI v2.0 Web services for any teaching and learning environment. The R2Q2 project aims to produce a complete engine to render and respond to all QTI v2.0 question types. The engine, illustrated in Figure 3, will be wrapped as a Web service so that it can both integrate easily into the

JISC e-Framework [10] and be exploited by other SOA applications such as those envisaged by the CVTLE.

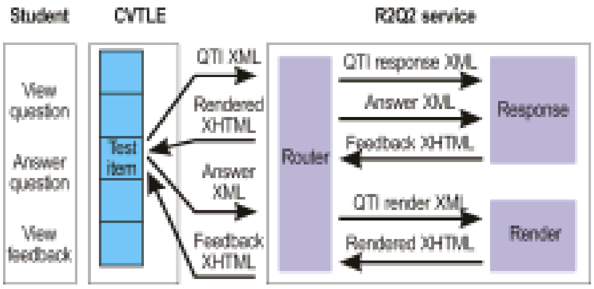

Figure 3: R2Q2 service

3.2 Learning design player

The IMS Global Learning Consortium standard for learning design (LD) is currently accepted as the standard to which teaching and learning environments should aspire. Coppercore is an open-source implementation of a LD engine or player which can be wrapped as a Web service, and can be integrated with other Web services [6]. Coppercore is not itself a Web service, however, and the JISC-funded Service-based Learning Design Player (SLeD) project [11] has achieved some initial success in providing an alternative. However, Weller's critical review [12] provides some warnings about the difficulties involved in a thorough-going SOA for the CVTLE. Although the endpoint may be desirable, the effort required to reach it may prove to be prohibitive.

3.3 Student personal portfolio

A student using the CVTLE would expect to maintain an independent 'personal portfolio', and would need the CVTLE to access and add to this personal portfolio as required.

A number of organisations are drafting standards for student portfolios. The IMS standard, for example, provides for a considerable list of items that might be included in such a portfolio, such as works created by the student, information about these works, information about the competencies, achievements, and preferences of the student, the results of tests or examinations, and so on.

To function within the SOA of the CVTLE, personal portfolios would need to be implemented as a service. The JISC-funded eP4LL project [13] is developing a service-oriented reference model for e-portfolios, but this is not currently scheduled to yield implemented services.

3.4 Enterprise administration

There are three identified areas where user (student) data is required by the CVTLE: the personal portfolio, the enterprise (university, college, school, etc) administration, and the user profile.

The enterprise administration service would be required to provide data about the student such as their group memberships and their course registration and enrolment, and to store data such as the results of their test, examinations, or assignment marks. The IMS standard for enterprise services provides for student membership and enrolment data. The standard notes the requirement for grade-book services (record keeping of marks and assessment results) which are presumably to be incorporated into the next version of the standard. That this is a developing area is shown by the fact that the IMS student personal portfolio standard also makes provision for recording student marks and the results of examinations. As database administrators are all too aware, holding the same data in two separate file systems is not considered good practice. Again, given these service standards, services need to be written so that a CVTLE can access this data.

3.5 User profile

The user profile data is held within the portal in the CORE, since the applicable community is small and stable. From this local data store, authentication, user management, and simple workflow control are easily provided. For the CVTLE, however, data relating to the user (student) profile is held externally, for example in the student records system of the enterprise.

The IMS student portfolio standard, discussed earlier, makes provision for holding certain student data such as learner preferences. The IMS enterprise services standard makes provision for holding authentication data that can identify, for example, whether a given student is permitted to access or to study given courses or materials. The 'user profile' requires both of these kinds of data to be accessible to the portal in order for the CVTLE to offer the appropriate, if not adaptive, teaching and learning services.

3.6 Control of teaching & learning

If the major teaching and learning workflow of the CVTLE is specified by its learning designs and is managed by the LD player, there remains a need to manage and monitor the student's use of the offered learning designs, the scheduling of tests and examinations, recording the times and sequence in which materials are exchanged with the repository and the personal portfolio, and so on.

The need for such management is identified in Figure 2 as 'Teaching & Learning control', and is uncomfortably close to the need for some kind of overview workflow for the CVTLE. This control layer is what Olivier [7] calls the setup and scheduling manager, what Vogten [6] calls the services integration layer, and what McAndrew [14] calls the services broker/dispatcher. It is the issue of Web services orchestration: coordinating asynchronous interactions, controlling flow, monitoring activities.

Figure 4 illustrates the communication between the teaching and learning control, portlets, and services. The teaching and learning control communicates with a service via an adapter or portlet. It is probable that the teaching and learning control connects to the portlet by using JSR 168 [5] while SOAP [15] is used for the communication between the portlet and the service.

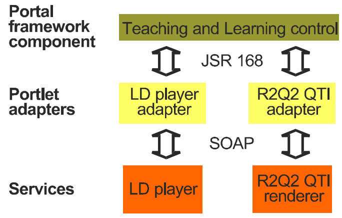

Figure 4: The connections of LD Player and R2Q2 QTI services to CVTLE

3.7 Repository

The CORE system used the Southampton University ePrints as its repository of research articles and reports in both draft and final form. While this system worked well (a service wrapper to ePrints was developed specifically for CORE), a more general approach to repositories is required.

Where the CORE VRE repository was oriented towards articles and papers, and experimental data sets were held separately by a data manager service, the CVTLE requires a general-purpose repository which additionally holds learning designs, questions and tests, and other teaching and learning materials.

The JISC funded the flag-ship Online Repository for Learning and Teaching Materials (JORUM) project which supports IMS Content Packaging and multiple metadata profiles, including the UK LOM Core, but this was not a service-oriented implementation. To move towards such an implementation, JISC have funded the Accessing and Storing Knowledge (ASK) project to build a SOA reference model and a demonstration implementation.

4 Conclusions

The CORE is a service-oriented VRE which has been successfully demonstrated. Its natural extension to a collaborative virtual teaching and learning environment, while relatively easy to show on paper, is less certain. Future work should address the following issues for a CVTLE.

- There are few implementations of the key services needed to demonstrate the CVTLE concept, though the R2Q2 project is developing a QTI service.
- The implementation of the SLeD service-oriented learning design player has raised questions about the feasibility of such an enterprise.
- Overlapping standards, particularly in the areas of personal portfolio and enterprise services, and also between IMS QTI and IMS LD, need resolution.
- Key questions about the source and use of user profile data remain difficult to answer.
- Finally, there remains the issue of service orchestration, coordinating, controlling, and monitoring the teaching and learning process. We purpose portlet adapters as a generalisation of the individual proposals in [6] and [14].

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A Learning Design Tool Implementation in ATutor

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Abstract: *This paper describes a project started at the Technical University of Sofia Research & Development Laboratory “E-Learning Technologies” and examines the implementation of a Learning Design Tool (LDT) in a Shareable Content Object Reference Model(SCORM), open source based e-learning environment ATutor. The main goals are focused on: building a template solution that supports and guides the authors in the Units of Learning design process; proposing a full documentation of the lesson plans in a purely presentable context in the form of MS Word file; reusing IMS LD packages. The design methodology includes two aspects: (1) a conceptual modeling based on an Educational Modeling Language and the IMS Learning Design Specification, and (2) a software development and integration. The implementation of the LDT is done by applying the following technologies: an object-oriented PHP language, HTML, JavaScript, XML and a relation Database.*

Keywords: Learning Design Tool, Implementation, Educational Modeling Language, IMS Learning Design Specification, SCORM E-Learning Environment

1. Introduction

To be successful, an e-learning must offer effective and attractive programs and courses to the learners, while at the same time it is providing a pleasant and effective work environment for the authors. Currently a lot of projects are building tools for the authors based on the IMS Learning Design (LD) specification concepts. The LD was developed from the Educational Modeling Language (EML) created by the Open University of the Netherlands. At the heart of the EML, is the idea that *Learners* perform *Activities* in an *Environment* with provided *Resources* and *Services* in order to achieve *the Learning objectives* according to a defined *Method* [1]. The EML is the basis of the IMS LD specification. The aim of this specification is to provide a digital format for encoding, transporting and playing learning designs, involving three levels. Level A contains the core of the IMS LD: people, activities and resources, and their coordination through the method, play, act and role-part elements. This simply provides series of time ordered learning activities to be performed by the learners and the teachers, using learning objects and/or services. Level B adds greater control and complexity through the use of properties and conditions. Level C offers the opportunity for more sophisticated learning designs through notifications, which allow for a notification of the new activities to be triggered automatically in a response to the events in the learning process [2]. The core components of the LD are based around the conceptual entity of a Unit of Learning (*UoL).* This is the smallest unit that satisfies one or more learning objectives. In the practice this may be a course, a module, a lesson or a single activity such as a discussion. The LD UoLs could be a whole course, assembled from a number of UoLs to make a full course.

The Learning Design approach is used in the project developed at the Technical University of Sofia R&D Laboratory “E-Learning Technologies” aimed at the design and the implementation of a Learning Design Tool (LDT) in a SCORM-compliant, open source e-learning environment, ATutor.

2. Needs Analysis and Requirements Definition

The creators of teaching materials continue to experience unnecessary difficulties in: the documentation of the teaching strategies used in or with any materials; the establishment and the adherence to the prescribed procedures in order to assure the consistency of that documentation;

the selection of the elements of a complete unit of learning, in order to allow the creation of new units of learning [2]. Some popular LD Tools, used by authors of UoLs include RELOAD [3], CopperAuthor [4], aLFanet [5], MOT [6], LAMS [7]. Some of these tools require much more front-loading of skills before useful results can be achieved and others require some level of technical skills. Griffiths provides a discussion on the various types of tools, and a diagram which places them on a quadrant of two axes: close to/distant from the specification and general purpose/specialized [8]. The RELOAD, CopperAuthor and aLFanet are Tools close to specification with a general purpose. The MOT and LAMS stand in the fourth quadrant quite distant from the specification and are with a general purpose. A big gap emerges in the Tools that are Distant from the Specification and with a Specific Purpose. It is clear that the authors need high level tools to understand the Specification, and exactly the tools that are specialized for a particular pedagogic context will be easier and faster to use.

The analysis of these LD Tools exposes some drawbacks:

- The RELOAD and CopperAuthor require some level of a technical knowledge to edit correctly the various fields.
- The extended functionality of MOT and LAMS supports the more general process of learning design that requires more time and user's attention to learn, setup, control and navigate the tools.
- End-user download, installation and maintenance procedures that waste time require system administrator's attention.
- The adaptation of these LD Tools for specific learning processes and exact pedagogic experiences can be a challenge.
- There are difficulties in integrating LD Tools with the Learning Management Systems.

The LDT requirement specification, defined at a different level of details in the context of needs, is the following:

- Functional: A tool that allows creation of a UoL, template-based LD Tool with best practice scenarios, a tool that supports authors giving them the basics of LD theory;
- Operational: a web-based LD Tool with a client/server architecture, with end user installation and maintenance-free, easily to be integrated with other e-learning platforms, that generates MS Word file and IMS LD content package;
- Management/organizational: tools and services of ATutor are used.
- Technological: for an easy integration in ATutor, the LDT has to be developed in an object-oriented PHP language, JavaScript, with MySQL Database communications, http/ftp protocols used.
- Standards-based: used EML and LD IMS Specification level A, used SCORM e-learning content.

The problems, which the LD Tool solves, are the following: 1) The LDT provides a template for authors/teachers who don't understand LD and guides them through the UoL design process. The template solution has been chosen because it is: a way of making things simpler and faster to the authors, a way to be focused on the pedagogical issues and not on the technical ones, a way to produce a practical UoL, instead of a full understanding of IMS LD, a way of disseminating IMS LD into the authoring community [9].

2) The LDT proposes a full documentation of the lesson plans in a purely presentable context as it generates MS Word file. The simplicity of the MS Word environment provides interface features which can help the authors to make sense of a UoL taxonomy. This in turn allows the authors to view, edit and evaluate LDs.

3) The LDT generates reusable IMS LD Content Package with an instructional content, resources for a given learning activity and the description of how those resources may be organized for the best instructional effect.

3. A Methodology of the Design and Development Process

The design methodology includes two aspects: (1) a conceptual modeling based on pedagogy concepts of Educational Modeling Language (EML) and the IMS Learning Design Specification and (2) a software development and integration which comprises of an object-oriented approach, a Unified Development Process (UDP), a Use Case Analysis, the Unified Modeling Language as well as a client-server architecture solution.

3.1. A Conceptual Modeling

The design and the development of the education is an incremental process which follows systematically the stages of analysis, design, development, implementation and evaluation. The instrumentation differs for each stage, depending on the specific goals, settings, and actors that play a role during that stage.

In the analysis phase, a concrete educational problem (use case) is analyzed, usually by talking to the various stakeholders. What matters here, is that the analysis results of the didactical scenario is captured in a narrative, often based on a checklist. The narrative then is cast in the form of a UML activity diagram in order to add more color to the analysis. This is the first design step.

The UML activity diagram then forms the basis for an XML document instance that conforms to the LD specification. This is the second design step.

This document instance subsequently forms the basis for the development of the actual content (resources) in the development phase.

The content package with both the resources and the learning design are then evaluated [2].

3.2. Software Implementation and Integration

The UDP is used as the main development strategy, relying on the incremental process model [10]. In the project, the UDP is chosen because: it is planned and managed; it is predictable; it accommodates the changes to the requirements with la ess disruption; it is based on evolving executable prototypes; it is risk-driven. The UDP consists of four phases: Inception, Elaboration, Construction, and Transition. The main stages, which are iterated through each increment, are: iteration planning, requirements capturing, analysis and design, implementation, test and prepare release.

4. A Use Case Analysis

The Use Case analysis is the most efficient method for the capturing of the requirements and software system functional specification. The Use Case analysis also helps to layout the actors or users and their role in the use of the system.

The main actors that interact with the LDT are as follows: the author (human actor), the Learning Management System (non-human actor) and the SCORM e-learning Content Editor (non-human actors).

A conceptual strategy for the building of the UOL is depicted in Figure 1 by six Use Cases: *Describe General Information for the UOL, Define the Roles, Describe the Activities and the Activity Structures, Describe the Environments, Define the Method and the Use Performance Support Tool.*

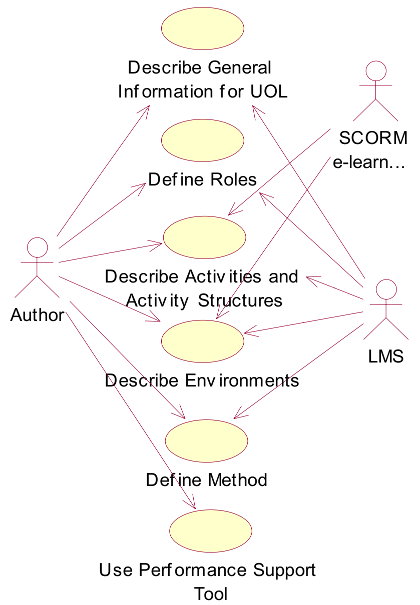

Figure 1 A Use Case Model of LD Tool

4.1. Describe General Information for the UoL

The Author makes a description about the UoL All the elements – Title, Summary, Keywords, and Author's Details define the metadata of the UoL.

The Author describes the main Learning Objectives for the entire UoL and the specific Learning Objectives per activity. The Author describes the Prerequisites (knowledge, insight, attitude, or competence; situational factors, e.g. availability of a specific hardware or other devices) to express the necessary requirements for starting a UoL. The LMS as an actor uses this information to provide different tools and services to users.

4.2. Define the Roles

The Author specifies the actors (the learner and the teacher) who play a role in a UoL, using the registered in the LMS and describes their roles.

4.3. Describe the Activities and the Activity Structures

The Author describes for each Activity - what should be done by the learner, how it should be done and defines when an activity is to be considered completed. The next step is for the author to assign the learning objectives, prerequisite(s) and resources to each activity, which has been defined in the previous step. SCORM e-learning Content Editor is used for the creation of e-learning resources. The Author also defines Activity Structures. The LMS manages the activities and the activity structures.

4.4. Describe the Environments

The Author describes the environments in which the activity should take place. The learning objects, which can be included in the learning environment, are: Knowledge Objects (Instructions, Learning Content), Announcement Object, Tool Objects (Wiki, Glossary, CAD Environment), Communication Objects (Chat, Forum, Email), and Test Objects (Quiz, Assessment). Learning objects are also managed by LMS.

4.5. Define the Method

The Method is important for the interpreting of the UoL. It includes plays, acts, and the set of activities or activity structures. The Author assigns activities to specified roles.

5. Architecture

The LDT is an integral part of the SCORM-compliant e-learning environment, as is depicted in Figure 2. The e-learning environment includes a LMS, a SCORM-compliant Learning Content Management System (LCMS), a Digital Repositories (MySQL DB, a SCORM content, XML LD files), and a LD Run Time Environment (RTE) and a SCORM RTE. The Author builds learning designs and creates e-learning content, the administrator manages and distributes the LD and content and the learner interacts with and learns by following scenarios in a UoL.

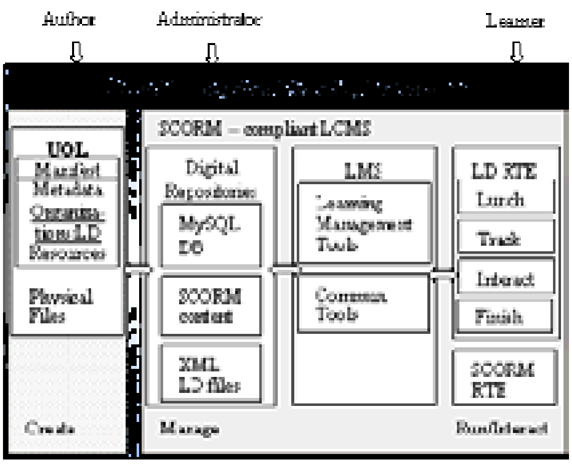

Figure 2 Functional Architecture

6. Implementation

The implementation is concerned with the building, testing, and deployment of the new LD software application. Specifically, this activity includes a detailed design of each LDT component (a user interface, a functions code and a database), a construction, and an integration of the code and user interface of the LDT in an ATutor. The implementation is largely dependent on the architectural choices, middleware and on the web e-learning environment used. An object-oriented PHP language and JavaScript, is used in order for the LDT to be modular. The Tool is developed as a distributed application using a client/server architecture with three basic flows. The first flow reflects the data movements between the web browser and MySQL DB. Some LD components as activities and environments need to be bundled with resources, and the second flow presents the inserting of SCORM content in UoL. The movement from the design of the UoL to the XML document instance is the third flow. The LDT prototype is presented in Figure 3. The software is placed on the server side. The Author works only with a web browser and populates the Form' fields in order to design the UoL on the client side. Several examples are presented in Figure 4, in order to illustrate the LDTs integration with the ATutor. The pilot test was started in December 2005 by experts from Regional Educational Departments and MSc students from Sofia University.

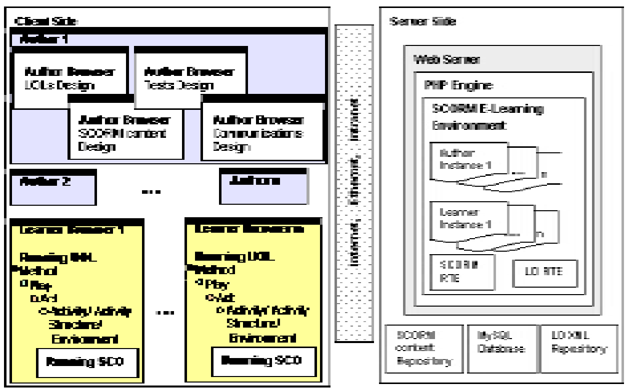

Figure 3 Prototype Architecture

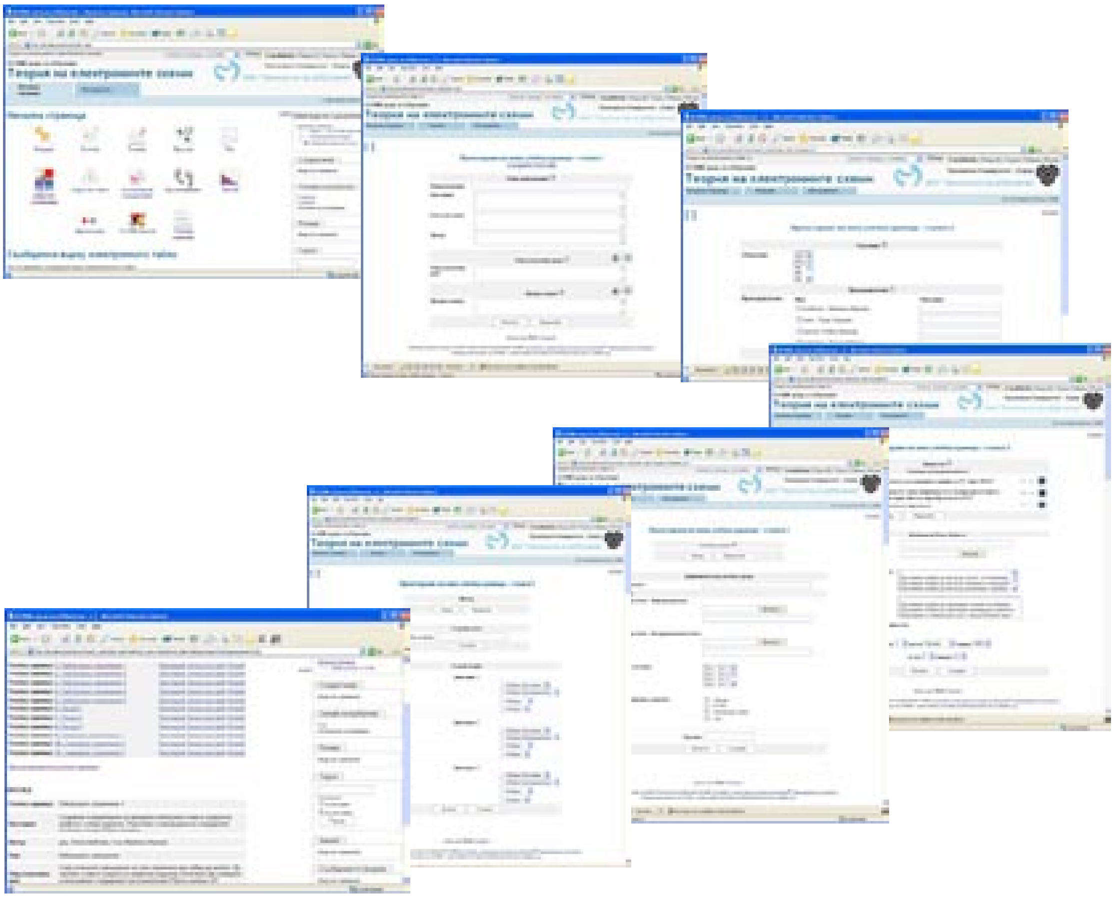

Figure 4 LD Tool Realizations

7. Conclusion

A significant step for implementing the new LD Tool as a part of SCORM-compliant e-learning system ATutor for the purposes of the higher education and training in Technical University of Sofia has been taken. The design and development of LDT, realizing LD concepts, have been presented in this paper. The Tool supports the author step-by-step, giving instructions to the authors. The main picture of LDT' characteristics and software system functional specification is defined through the Use Case analysis. The developed prototype architecture of LDT has been presented in a client/server architecture. The graphical user interface is constructed and the application logic is coded in PHP, HTML, XML and JavaScript. The key targets for a future development are the modification and the upgrade of the LD Tool to levels B and C.

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Positioning of Learners in Learning Networks with Content Analysis, Metadata and Ontologies

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Abstract

Positioning in learning networks is a process that assists learners in finding a starting point and an efficient route through the network that will foster competence building. In the past we explored computational approaches to positioning that are based on the contents of the learning network and the behavior of those participating in it, more or less ignoring different efforts to stimulate positioning and competency development from a top-down-perspective. In this paper we introduce and compare strategies for positioning and give a research outlook for computer-assisted positioning.

Keywords: positioning, learning networks, competences, latent semantic analysis, metadata, ontologies.

1. Introduction

How to find one's way in lifelong competence development is a topic addressed by the European Union at a very general level [1]. For lifelong learning orientation is an important success factor and learners want to have learning opportunities fit to their current situation and needs. A traditional approach to address this problem is the accreditation of prior learning (APL). APL offers methods and techniques to identify prior learning experiences from formal and informal education. This procedure is especially important if a person crosses the boundaries between work and learning or between academic disciplines. Most of the APL methods rely on experts who study the learner profiles and decide which parts of educational programs could be exempted and which ones are best suited as starting position for the student. But this way of positioning a learner is a very time-consuming and expensive approach. Therefore we want to concentrate on computational approaches to address this problem for lifelong learning. The foundation for this approach is the idea of learners acting in so called learning networks.

A learning network connects actors, human as well as agents, institutions and learning resources. Information and communication technologies are used in such a way that the network self-organizes [2]. The actors in the learning network share one common goal: furthering the development of competence by learners. Competence is defined here as effective performance in a domain at different levels of proficiency. Competences include skills and they can be divided in 5 main competences (cognitive, functional, personal, ethical and meta-competences) [3].

Learning networks are aimed to support various forms of learning, including non-formal learning. In formal, academic type of learning learners engage in series of learning activities that may take years to complete. In learning networks for lifelong learning, prolonged interruptions of such series of learning activities are likely to occur. Moreover, learners may engage intermittently in different types of learning. Whenever such a learner returns to the learning network we are faced with what we call the 'positioning problem': Taking into account the goals and the history of the learner, what route or routes of learning activities through the learning network can we advise and what is the best place for the learner to start? [4].

Positioning means to map the competences of a learner - which should be stored in some kind of learner profile - with the competences that result from the competence development program. Assume that the learning network contains pre-arranged routes towards particular goals and that every route is a competence development program. Then, the positioning problem is one of determining which learning activities in the routes need to be completed and which ones can be skipped, because they do not add to the competencies, skills and knowledge that the learner has acquired in the past. How exactly the competences of the learner and his history can be mapped onto the learning outcomes of activities in the learning network, is far from clear because the data to be used are ill-defined.

Learner data may result from formal, accredited learning as well as from experience gained in informal learning situations. Description of competencies may range from completely absent to being based on an ontology or at least a controlled vocabulary. We seek computational approaches to positioning that ultimately fulfill the criteria of reliability (the same situation leads to the same recommendation) as well as validity (the recommendation matches that of experts).

We surmise that alternative approaches to positioning need to be based on the type of competence description (of learners as well as programs) that are available. The Positioning Situations-Matrix in figure 1 depicts several different situations.

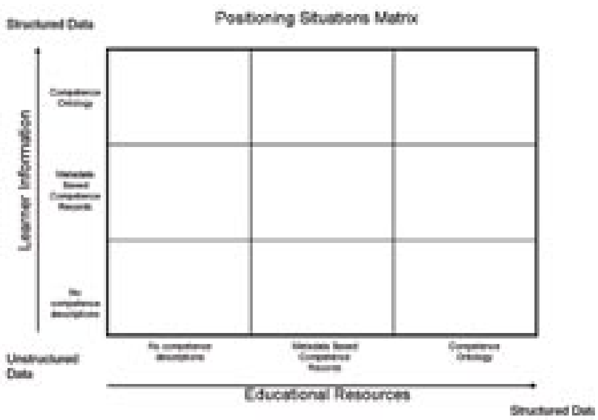

Figure 1: The Positioning Situations Matrix

In this paper we discuss several cases:

Case 1: Informal descriptions
The learner enters an educational environment without any profile or competence descriptions. The competence development program is highly informal without information about the connected competences. Here, a content based approach, as discussed in section 2 is best suited for positioning.

Case 2: Standards based positioning
If a learner enters with a standards-compliant ePortfolio the situation would be different for a positioning service. In section 3 we review and discuss these standards and the way they can support positioning.

Case 3: Ontology-based positioning
If there were competence ontologies inside the learner profiles and the competence development program the positioning problem can be based on mappings between the ontologies.

The three cases discussed here represent only the "symmetrical positioning" where similar data have to be compared – the more complicated positioning would be the "asymmetrical positioning" where for example a competence ontology in the learner profile should be mapped to the content of a competence development program.

To cover all these different situations and to ensure the best achievable position inside a competence development program we compare two different approaches: A content-based approach using Latent Semantic Analysis (LSA) and a Metadata-Based-Approach based on different standardization efforts and semantic-web technologies. In the next sections we present these approaches and discuss their merits in the final section

2. A Content-Based Approach to the Positioning Problem

The rationale and the research agenda for a content-based approach to positioning was described in [4]. The approach rests on the following assumptions. It does not aim to *directly* demonstrate that the learner has already acquired knowledge, skills and competences that are equivalent to the outcomes of learning activities within the routes considered. The core assumption is that equivalence of outcomes will be reflected in, or can be approximated by, the similarity of the *contents* of (learning) materials studied or produced by the student (source material) and the material contained in the learning activities in the learning network (target). If a positioning service determines that the content of source and target materials overlap substantially, the target activity is exempted.

In our content-based positioning service document similarity is computed using latent semantic analysis (LSA) [5]. LSA is based on word (co)-occurrences in documents, thus all order (syntax) of words or semantics in the original documents is ignored. All analyses are performed on a Term-by-Document matrix with word frequencies in the cells. The dimensions of this matrix are computed and the largest dimensions found (the semantic factors) are retained to reproduce the original matrix [6]. In the reproduced matrix each document is represented as a vector. The smaller the angle between two document vectors the higher they are correlated, that is, they are expected to contain materials that have substantial overlap. Learners are represented by one or more documents that they have produced or studied. If one or more of these learner document vectors demonstrate a high correlation with learning material vectors, then the learning material may be considered redundant.

Although the content-based approach has modest requirements on the way data are expressed, there are several limitations and assumptions that we need to consider. These will be discussed in section 4.

3. Metadata-Approaches for the Positioning Problem

Several efforts from standardization bodies and working groups aim at unifying competency descriptions and competency levels. Note that these standardization efforts are all focused on competency and not on competences as we understand them. We consider standards to express competencies and portfolios.

The IMS Reusable Definition of Competency or Educational Objective (RDCEO) specification aims at a standard description of competencies and educational objectives for online and distributed learning. RDCEO is expected to promote common understanding of competencies that can be used in competency development (learning and career development) or in specifying learning pre-requisites or learning outcomes [7]. The RDCEO offers a unique identifier to assign an unstructured competency description to an object for example in a Unit-of-Learning (UoL). Based on the RDCEO a draft standard for Reusable Competency Definitions (RCD) is being defined in the IEEE. Although RCD does not intent to offer a solution to the aggregation of competencies from sub-competencies the data-model allows the integration of relational information or competence ontologies through embedding additional metadata [8].

For portfolios two specifications are of interest. The IMS Learner Information Package Specification (LIP) is designed to package learner information for the exchange of data [9]. The IMS ePortfolio specification builds on the LIP specification to ensure portability and exchange of ePortfolio records for learners [10]. The specification is addressing different usage possibilities (assessment, planning of learning) and it can store produced artifacts form the learner and formal achievement records like references.

A slightly different approach comes from the HR-XML Consortium. The consortium develops a standard suite of XML-specifications to allow the exchange of Human-Resource-related data, such as a competency schema for a variety of business contexts that is applicable in recruitment processes [11]. The model allows the evaluation, rating and ranking of competences which are an important issue in recruiting processes.

These metadata were all connected to the learner profile but another important standard for the content of the competence development programs is the IMS Learning Object Metadata (LOM). The LOM is used to assign metadata to learning objects. For the positioning service it is important that there is no element in the LOM standard to store competence related information at the moment [12]. They could be stored in the educational segment of the metadata as proposed in [13] but this does not seem to be a widely adopted solution to the problem.

Nonetheless in case 2 of the positioning problem competence descriptions in these metadata could be used for positioning by mapping them and finding similarities between the descriptions. As the underlying data models differ in these standards because they stem from different organizations and bodies the development of a crosswalk for competence-related metadata could be fruitful to address this problem. A crosswalk is a specification for mapping one metadata standard to another [14]. One can imagine that it could still make sense to combine these approaches with one that is content-based.

The specifications discussed here allow the integration of external competence models. They make (meta-)data available for positioning services, and may serve the purpose of opening more data for content-based positioning. The standardization activities alone, however, have a limited usefulness for competence mapping and the formalized description of complex competence relationships. The interoperability standards discussed above serve the purpose of sharing data. They themselves do not ensure the semantics of the data, i.e. there are still different ways to describe the same learning outcomes, such as competencies.

The missing link between the standards and the competency mapping may emerge from the use of competence ontologies and semantic web technology [15]. Ontologies are metadata schemas providing a controlled vocabulary of concepts and they can be useful to share common understanding in a domain in a machine-readable way. For competence development ontologies or taxonomies can be used to define competences related to competence development programs. Competence ontologies could be either added to the learner profiles [16], learning objects [12] or the competence development programs [17]. But the design and implementation of competence ontologies is still a very complex and time consuming task. In an ideal situation every learning network could share a common understanding of the competences needed for successful running through the program based on ontologies. The ontologies in the programs could be added to the learner profiles step-by-step after they have successful passed the connected assignments. In this case positioning could happen through the mapping of competency descriptions inside the learner profile with the competency descriptions connected to the competence development program. This technique is called semantic matchmaking [18, 19].

In the next part of the paper we will discuss the presented approaches and try to give an outlook for our research on positioning in the future.

4. Discussion

Positioning a learner in a learning network for lifelong learning is a complex task by itself and this is exacerbated by conditions that prevent any simple mapping of learner profiles and competency descriptions onto the educational resources. The two most extreme situations that we considered are the clearest: (1) no competency descriptions inside the learner profile and the program and (2) competence ontologies in the learner profile and the program. In the first case a content-based approach is the one to take.

The content-based approach to the positioning problem has the advantage that it can be used for positioning right now, where most learners do not have an ePortfolio or competence profile. The drawback of the approach is that it is only related to the produced content of the learner and not to his earned competences. So the success is dependent on the amount of text the learner can provide in relation to his educational history. If he can for example only add content from several parts of his educational background, the positioning recommendation will be biased. Additionally, the concentration on content may effectively limit the approach to domains with a strong verbal character. For the same reason, domains with psycho-motor content, for example practical skills, may not be adequately represented.

In the second case a mapping of ontologies could be a feasible technique to reach the ideal position for the learner. For the positioning problem all the data models can be useful because having machine-readable information about the competences of the learner simplifies the positioning task if we have also competence descriptions inside the chosen competence development program. But, there are drawbacks to this approach and those related to it: all the presented metadata-based initiatives offer a way to ensure a standardized description of competence related data. The models differ from openness (in terms of the possibility to embed ontologies or taxonomies) and intention (packaging focus or description focus). But the biggest drawback with metadata- and ontology-based approaches is the economical side of the medal. A huge amount of work has to be invested to enrich learning resources and learner profiles with metadata and competence ontologies. Another problem is that metadata and ontologies are always arbitrary models to a knowledge domain and that objective ontologies don't exist [20]. Besides it is very expensive to let domain experts guarantee the quality of the metadata used. Several experiences from repositories have shown that it is not an advisable idea to pass the burden of metadata-enrichment to the users. The quality of user created metadata cannot be compared to the quality of experts [20, 21, 22].

Our research will focus in the future on computational approaches to address the three presented cases for positioning of learners in learning networks. While there are already several individual experiences in all of the presented cases a combination of them is a new approach for the positioning problem. We will experiment and apply our theoretical results to a real-life example from an introductory psychology course of the OU NL and we will address all cases with different experiments. Students will be provided an ePortfolio to collect information about their educational background and their prior learning experiences. Those learner profiles will be compared to the course content and the related competence descriptions. For the second case we will enrich learner portfolios and course content with competence related metadata. For the third case we will develop a very small competence ontology and address the problem of competence similarity and competence growth. In this part of the research we will address also the problem of domain independent competences which play an important role for lifelong learning. The question is how we can transfer achieved competences in one domain to competences in another domain. For case 2 and case 3 we will research combinations of different data for a recommendation for a starting position. The project will use techniques and methods from research on recommender systems for the development of a positioning service.

While the focus is on the comparison of similar data it is still an open question how an asymmetrical positioning could be addressed.

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Navigational support in lifelong learning: enhancing effectiveness through indirect social navigation

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Abstract

Efficient and effective lifelong learning requires that learners can make well informed choices from the vast amount of learning opportunities available. This paper suggests to help learners find their way by analysing choices made by learners facing the same navigational decisions in the past and feeding this information back as advice to present learners. The paper describes a tool developed to deploy this principle of indirect social navigation through collaborative filtering. The tool was tested in a controlled experiment with the experimental group using the tool and the control group not receiving any recommendation but choosing from a list of otherwise identical topics. Positive effects were found on effectiveness (progress and completion rates) though not on efficiency (time taken to complete) for the experimental group as compared to the control group.

Keywords: indirect social navigation, lifelong learning, Learning Networks, self-organisation, collaborative filtering

1. Indirect social navigation

Determining a path through education can prove challenging to an extend that it results in lack of progress or even drop-out [1 – 5]. In lifelong learning, where learning opportunities reach beyond institutional boundaries, traditional approaches to navigational support like pre-planned routes are inadequate. The concept of Learning Networks [6] addresses facilitation of lifelong learning. Learning Networks (LNs) are self-organised, distributed eLearning systems designed to facilitate learner controlled lifelong learning. Self-organised means that organisational structures evolve bottom up, from the actions and interactions of individuals, rather than being pre-defined. The Network contains units of learning offered by different educational providers, directed towards attainment of a certain competence level. To attain a certain level of competence different paths can be followed through these offerings. So what path best to follow through the units of learning that have to be completed in order to achieve the desired competence level? Alternatives to one-to-one advice and pre-planned routes for navigational support can be sought in several directions [7]. Social navigation, e.g. presentation of student views [5], is one of the alternatives. However, social filtering systems using explicit ratings require a large number of ratings to remain viable and users might consider it too much of a burden to rate units of learning [8]. A way to avoid this is to rely on indirect social navigation, a concept closely related to the principle of self-organisation.

For self-organisation to occur, actors have to have a high level of interactivity and access to feedback concerning the performance of similar others in the network [9]. This does not necessarily require *direct* interaction: traces left and modifications made by individuals in their environment can provide indirect feedback [10]. Where Rovai [4] states that “other students, staff, and faculty may not be readily accessible that can provide students with the information that they seek”, using indirect feedback might help bridge the gap: other students may be consulted as a source of information, albeit indirectly. Similar to collaborative filtering used in recommender systems [11], our approach exploits information on former user behaviour to make a recommendation to a presently active user. In our study, learners were offered feedback regarding the best next step, based on the number of times a unit of learning had been *successfully completed.* A unit of learning was successfully completed when a learner passed the associated assessment. In order to feedback this information, a collective log of learner interactions is used as described in Tattersall et al. [7]. The feedback is calculated as follows: if a unit of learning 'Y' has been completed by 10 learners and 4 of those learners went on to successfully complete 'X', whereas 2 went on to successfully complete 'Z', the advice for the next best step to a learner who has just completed 'Y' as a first node, will be a random draw from the set {X, X, X, X, Z, Z}. Taking a random draw ensures that the most frequently completed unit of learning is most likely to be recommended, while leaving room for other successfully completed units of learning to be recommended as well, thereby avoiding sub optimal convergence to a single next step [9].

We expect that the navigation tool will enhance both *effectiveness* (i.e. producing the desired effect) and *efficiency* (i.e. producing the desired effect with a minimum of effort) in LNs because offering more learner centred (i.e. related to learner's present position) planning information will facilitate planning decisions and reduce the risk of information overload. Moreover, as the feedback makes use of success rates, we expect learners to make better choices based on "tried and tested" sequences. The impact of offering this feedback on effectiveness and efficiency has been tested in a true experiment [12]. Effectiveness was considered in two respects: the amount of progress made and goal attainment [13]. Efficiency was defined as the time taken to attain the goal.

2. Method

The navigation tool was deployed in a Learning Network consisting of eleven units of learning, delivered on-line on the subject of the Internet. Participation in the LN was free for the target group of adult learners who have some experience with Internet (surfing the web and using email) and who face questions like: How safe is it to buy things on the Web? How to search for information on the Web? Participants were randomly assigned to an experimental group that was offered feedback and a control group that proceeded through the Learning Network without any feedback.

In order to encourage goal attainment completion of all eleven units within the three months experimental period was rewarded with a certificate. An e-mail newsletter was sent as a reminder of the closing date, ten days prior to the end of the experimental period.

The LN was created in Moodle [14] and modified so that an overview of the units of learning was available to all learners listing completed and to be completed units of learning separately. For learners in the experimental group the overview additionally showed an advice: "Continue with: [the best next step, based on successful choices of other learners]". Like participants in the control group, learners in the experimental group were told they could study the units of learning in any order but were advised to follow the recommendation. Figure 1 shows the overview for a learner in the experimental group. The order of the list of units of learning still to be completed was reshuffled each time the page was viewed so that there would be no effect in the sequencing of units of learning due to the presentation in a fixed list.

A group of 1011 people enrolled and were randomly assigned to either experimental group or control group. However, twenty percent never actually visited the website. They were excluded from the study, leaving a group of 808 learners: 398 in the control group and 410 in the experimental group.

3. Analyses

The effect of the feedback offered on the amount of *progress* made was measured through multivariate analysis of variance for repeated measures [15].The average number of completed units of learning was measured four times at three weekly intervals. The effect on *goal attainment* was tested comparing the proportion of learners having completed all 11 units of learning at the end of the experimental period in both groups using a χ^2 test. Finally, the effect on *efficiency* was tested using a t-test to compare the average time taken to complete 11 units in both groups. The time taken to complete was measured by counting the number of days between initial login and completion of the final unit of learning.

4. Results

The overall completed units of learning over time was denoted by a significant positive linear trend ($F(1,806)=586.91$, $p<.001$) and a significant positive quadratic trend ($F(1,806)=10.55$, $p<.001$).

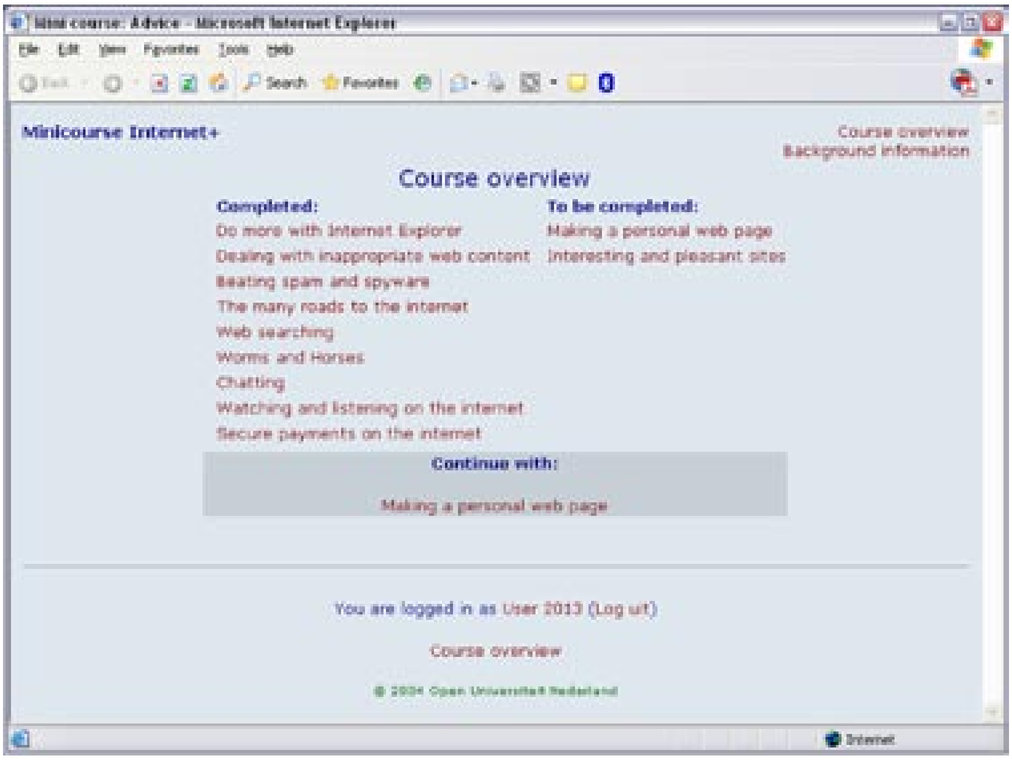

Fig. 1. Overview for a learner in the experimental group

But a significant effect of group on the quadratic trend was found ($F(1,806) = 4.96$, $p < .05$). Simple effects analysis showed that in the experimental group progress developed along a straight line, whereas in the control group the amount of progress made accelerated towards the end. Figure 2 illustrates how the average number of completed units of learning is consistently higher in the experimental group except for the final measurement. This shift towards the end may have been influenced by the intervention of reminding learners of the course deadline ten days prior to the end of the experiment. To test whether this intervention may have had an unintended and different impact for both groups, a repeated measurement analysis was performed for the last three weeks showing that the intervention indeed only had an effect for the control group [13]. Subsequent analyses corrected for the unexpected and unequal effect of the course deadline reminder and showed a significant effect for group ($F(1,806) = 4.32$, $p <.05$) on the number of units of learning completed, indicating that the amount of progress made by learners in the experimental group was significantly higher over the period up to the intervention.

Results for *goal attainment* immediately prior to the intervention showed a significantly higher percentage of learners completing all 11 units of learning in the experimental group (40,2%) than in the control group (33,4%) ($\chi^2 = 4.04$, df = 2, $p < 0.05$).

Finally no effects were found regarding efficiency. At the point of intervention, the average number of days elapsed between enrolment for the first unit of learning and completion of the 11th unit of learning was 36.49 in the experimental group, compared to 38.96 in the control group. Although learners in the experimental group reached the goal in fewer days, a t-test comparing these means shows that this difference is not significant.

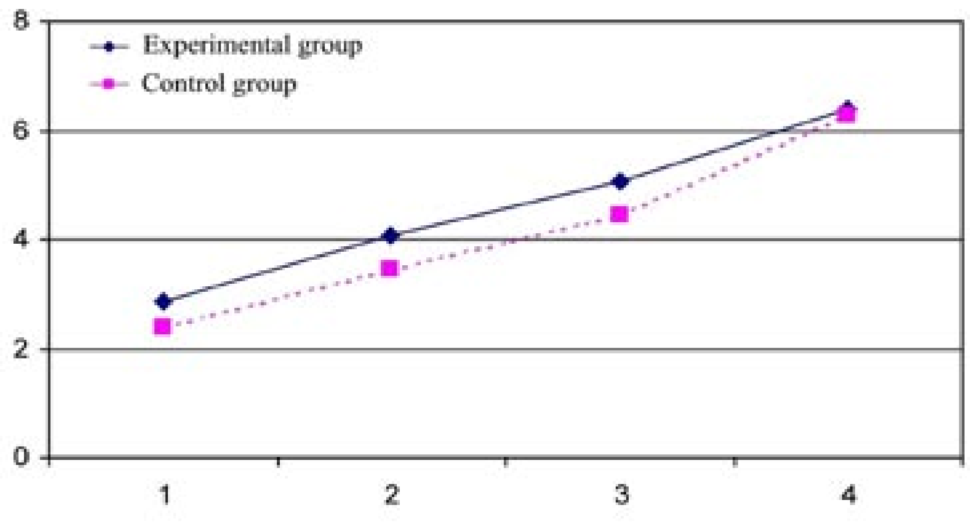

Fig. 2. Average number of completed units of learning (Y axis) at four successive moments (X axis) for experimental and control group.

5. Conclusions and discussion

Offering navigational support based on feeding back the choices of successful learners enhances effectiveness though not efficiency in lifelong learning. However the use of a rather crude measure of efficiency (elapsed time rather than actual study time) may mask significant differences in efficiency between the groups. Subsequent work would benefit from a more accurate measurement of study time.

The recommender tool was tested in a rather small and static Learning Network while in reality LNs are dynamic: courses will be added, deleted and changed. A challenge for further research will be to integrate these dynamical aspects in the system. At the moment we are developing mechanisms to support dynamical networks.

Besides research is carried out currently to investigate whether the effects found in this study can be improved by further personalisation of the approach, taking into account both characteristics of students and properties of the units of learning in the network, leading to recommendations like for instance the best next step for women or the over fifties.

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European Lifelong Competence Development: Requirements and Technologies for Its Realisation

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Abstract – *In the TenCompetence project, we aim to address the growing need for lifelong development with an open source framework for competence development programmes. We envisage that the framework will be used for formal, non-formal and informal learning activities; learning units will be created and shared in a distributed manner in learning networks, and peer-to-peer learning activities will be highly important. In this paper, we give an overview of the requirements and techniques needed to achieve this goal. Methods for learner assessment are needed for individualizing learning programmes. The system should provide functionality to position the learner in and around learning programmes, and to generate personalized navigation paths that match the learner goal; in addition, learners should be able to organize their learning process and to communicate. We discuss several existing tools and standards that may be used as a basis for the framework.*

Keywords: lifelong learning, Competence Development Programmes, methodology, positioning, navigation, learner support, assessment.

1 Introduction

In our largely knowledge-based society there is a growing need for continuing professional development, in order to deal with the evolving character of professional knowledge and technologies. Currently, education at high schools and universities is considered just the mere beginning of a process of *lifelong learning* [3]. Those learning activities that are aimed at maintaining or increasing the level of a worker's *competence* are generally called *competence development programmes.*

Competence development is generally not limited to formal learning activities that lead to certificates or degrees; many lifelong learning activities can be characterized as *non-formal learning* – on-the-spot training, possibly offered by peers –, or as *informal learning* – the acquisition of knowledge and skills by practice rather than intentional learning [4]

In order to support these activities, a technological infrastructure is required for storing, organizing and sharing the various bodies of knowledge; in addition, this infrastructure should provide lifelong learners with learning units that fit their individual background knowledge, learning objectives, and other needs.

Technological support for learning activities is not a new concept; a substantial amount of research has been carried out in the field of *adaptive and intelligent Web-based educational systems* [2]. However, the broader field of competence development poses several additional challenges and requirements, as compared to mere educational programmes.

In this paper we provide an overview of requirements and technologies needed for the realisation of lifelong competence development programmes. The aim of the European Integrated Project TenCompetence is to target these issues by integrating and extending existing models and systems into a common open source infrastructure.

The remainder of this paper is structured as follows. In the following section we introduce the concepts of competence and competence developments programmes (CDPs) in more detail. In the third section we discuss the need for a learner assessment service, and various approaches toward learner assessment. The fourth section describes the core services that need to be provided by the TenCompetence infrastructure: learner positioning in a learning programme, navigation support that matches the learner's individual needs, and general support for organization activities and communication. In section five we discuss several existing tools and standards, and indicate to what extent they would fulfil our requirements. The paper ends with some concluding remarks.

2 Competence Development

In this section we briefly discuss the concept of competence, and provide our vision on competence development programmes for lifelong learners.

2.1 Competence

Cheetam and Chivers [3] define competence as 'overall, effective performance within an occupation, which may range from the basic level of proficiency to the highest levels of excellence'. A key observation from this definition is that the concept of competence relates three different dimensions:

- a person's *competencies*[1] - knowledge, skills, attitude, or any psychomotor or mental activity which may require mastery [3][10];
- an *occupation*, which may range from hobbies and sports to professions; we prefer to use the more general term *context* instead;
- the *proficiency level* of a person with respect to a context; proficiency may be expressed by a collection of skills, by some demonstration of appropriate behaviour in the context, or by competences in related contexts.

As persons may have various occupations, they may have various levels of competence for each occupation. For example, John might excel in his job as a dentist, but his qualities as an orthodontist are mediocre. Yet, there is an overlap in the knowledge and skills required for both professions, and skills learned in the former profession might increase competence in the latter profession.

2.2 Competence Development Programmes

We define Competence Development Programmes (CDPs) as formal, non-formal, or informal collections of learning activities and units of learning, which are used to build competence in a certain discipline or job. The learning activities and units of learning are relatively independent from each other – as compared to a unit of learning, which is a tight integration of learning activities. Depending on the competencies to be built, these programmes can be small or quite extensive.

We envisage that CDPs can be greatly facilitated by so-called *learning networks* – people, institutions, learning objects and autonomous agents, which are connected by ICT networks [10]. Within these networks, learning units can be created and shared in a distributed, self-organized manner. In a sufficiently large learning network, the various bodies of knowledge existing in the group allow for the creation of learning programmes that fit an individual learner's need. These programmes may include formal programmes offered by institutions, but may just as well be the result of peers exchanging knowledge with one another.

In the field of Web-based educational systems technologies for *adaptive group formation*, *peer help* and *adaptive collaboration support* are well-researched areas [2]. These forms of group learning allow learners to discuss with one another, to find the most competent peer to answer a question, share learning routes, provide useful annotations and links, and to stimulate one another. In the context of competent development programmes these ideas can be extended to professionals exchanging knowledge and instructing one another.

Clearly, if a learning network would mainly be based on self-organized, peer-to-peer networks, it would be hard to assess the quality of any competence development programme. For this reason, there is the need for a formal specification of the programmes, and assessment of their effectiveness. In the field of CDPs several specifications of curricula and training programmes exist [e..g 9]. One of the goals of the TenCompetence project is to find a mix between these formal learning programme specifications and experiences with informal (group) learning activities into a specification to guide lifelong competence development programmes, as envisaged in this section. The various aspects that are relevant to this goal are dealt with in the upcoming sections.

3 Assessment Service

Within a competence development programme, there are several points at which the learner's competence needs to be assessed. In order to ensure that the learning material can be adapted to the learner's capabilities and goals, it is necessary to assess the learner's *existing competence levels* upon entering a CDP. In a network like TenCompetence, assessment of prior competences is far more important than in standard formal education, as learners may enter the network at various moments within their learning career. Consequently, upon entering, their level of prior competences will be very diverse. As the learner proceeds through the CDP, so-called formative assessment is needed *to guide the learner.* Based on the results of interim assessments, the learner's personal CDP can be adjusted either by a tutor or by the system. Finally, so-called summative assessment is needed *to determine whether the learner has successfully proceeded* to a next proficiency level of the competence involved.

An important role in all three types of assessment will be played by the learner's *e-portfolio*, in which all kinds of evidence of the learner's achievements are collected, such as prior work, results of units of learning, papers and reflections. Parts of the e-portfolio may be constructed explicitly by the learner or the tutor; implicit (automated) distillation of evidence data – such as the content of written

[1] For sake of simplicity and due to the overload of the term competency, we will use skill as a synonym henceforth. We do acknowledge that the term skill only partially covers the concept of competency.

reports – into e-portfolio contents is an alternative strategy which may reduce an enterprise's need to continuously track the human factor.

In addition to e-portfolios, various other forms of assessments can be thought of. Learners may engage in some form of self-assessment, or the assessment can be performed by a tutor or through online tests.

The challenging task for us is to formulate requirements for the development of efficient and effective assessments within a CDP, and more specifically requirements on e-portfolios.

4 Core CDP Services

As all learners who enter a network of lifelong learning have their own expertises, goals and learning styles, it is a challenge to match the individual characteristics with the possibly vast variety of learning content. One of the main goals of the system is to provide learners with selections of material that fit their background and learning goals, and not to force them to follow one predefined programme for each competence that they want to achieve. This implies that the system should be able to generate individualized programmes, and to support the learners in their progress – or at least to foster the support for the professional tutors.

To be capable to respond to these tasks, a number of core services is defined that are specific to the needs of competence development:

- a *positioning service*, which maps the learner's background onto a learning programme;
- a *navigation service* that generates or adapts a programme, based on the learner position;
- a *learner support service*, which provides a framework for the organization of learning activities and communication with one another.

These services will be explained in more detail in the remainder of this section.

4.1 Positioning Service

As multiple providers, and even learners, are expected to contribute to the network, mechanisms are needed to determine where learners can be positioned in this network [13]. *Positioning* is the process of mapping learner characteristics – as received by an e-portfolio or by a personal competence development plan – onto learning programmes, which consist of learning units in a learning network. These learner characteristics may include learner goals, prior knowledge and the interaction history. The position process should enable to select those learning units that are relevant to a learner's individual goal, and to leave out learning units that are not relevant, already known, or beyond a learner's current capabilities. In formally accredited competence development programmes, this step would provide obligatory items and formal exemptions; in informal programs, this step would generate recommendations. Such a service requires prior competence assessment, the creation and maintenance of e-portfolios and finally the allotment of learners to courses.

Considering the nature of the network envisaged, maintaining data on these characteristics and ensuring their integrity are difficult tasks. Several issues will need to be solved, like the selection of suitable approaches toward learner assessment, preferably as efficient and as autonomous as possible. A further issue is the mapping of the raw data from the user e-portfolios – which may contain lists of finished courses, their descriptions, questions asked and answers given – to a model of the learner in the learning environment.

We are currently exploring several fields to deal with the challenges given here. Various approaches can be thought of, including *content-based* techniques such as LSA, *usage-based* techniques such as clustering and stereotyping, *logical* representations and reasoning mechanisms, *collaborative filtering* and *Semantic Web* techniques.

4.2 Navigation Service

Once the learner has been positioned in a learning network, there is the need for an adaptive and flexible approach to provide the learners with means for orienting and navigating through a learning network's learning courses and units [12]. Predetermined fixed paths in accredited programmes restrict the possibilities of self-direction of the learner and are not necessarily the most appropriate sequences for the individual needs of a learner. Regarding non-accredited programmes on the other hand, the learner is on his own, which may quickly lead to frustration and drop-out, because of the lack of overview.

In order to cater the individual learner needs, the TenCompetence system will need to provide adaptive navigation support that puts the learner centre-stage. From the field of adaptive hypermedia [1] several personalization techniques can be borrowed. These include *individualized overviews* of the learning courses and units, and the learner's history; *relevancy indication* of internal or external links within the network; *guided tours* and *collaboratively* generated trails, *recommendations* and *annotations*.

4.3 Learner Support Service

The TenCompetence network will be particularly attractive to self-directed learners, who can plan themselves which learning programmes to follow, at what times, at which location, and with what speed. However, in particular in these kinds of non-accredited learning programmes, learners often lack a tutor to offer support, when needed.

Furthermore, the lack of feedback and interaction with peers may lead to motivation problems.

To address these issues, Kester et al. [7] proposes the following approach toward *peer-to-peer tutoring*: if a learner issues a content-related question to the system, the system will first try to find an appropriate answer in the existing resources, such as FAQs, forums and user-editable wiki pages. If the result would not sufficiently meet the learner's expectations, the learner could decide to ask help from a peer-tutor. It will be the system's responsibility to select the most suitable candidates. Ideally, a peer-tutor should be sufficiently experienced in the relevant field, but preferably not too far ahead of the learner; in this ideal situation both the learner and the peer-tutor can draw benefits from the interaction. Following the same principle, transient communities of peers interested in the same topic can be created, who can support and motivate one another. In addition, professional tutors can be contacted to further support the process.

5 Specification and Tools for CDPs

In order to allow wide adoption of the CDP standard, it is necessary to develop appropriate tools, or to adapt existing tools for the management and manipulation of such CDPs within the TenCompetence environment. The compatibility of *Free and Open Source Software* (FOSS) with interoperability standards and specifications is evaluated while seeking reusable components. In fact, the lack of information exchange between present-day e-learning systems highlights the need to adopt interoperability standards in future developments.

In principle, interoperability relies on a coherent set of e-learning specifications, which are formulated by bodies such as the IMS Global Learning Consortium Inc., in order to standardize and to facilitate the exchange of functionalities and resources.

5.1 Overview of Existing FOSS

During the last years, a number of e-learning design projects have yielded a set of specialized tools based on IMS Learning Design (LD) and Question & Test Interoperability (QTI) specifications [6], to promote coordination between distributed learning environments and content from multiple authors. These tools basically cover design-time editors that allow authors to construct CDPs and other related materials, as well as run-time players that dynamically provide learners with the appropriate resources and functionalities during learning activities. While a comprehensive overview of reusable e-learning tools and components is outside the scope of this paper, there are a number of published surveys and previous works that provide such overviews [5] [11].
In general, Griffiths et al [5], concluded that current FOSS authoring tools are scarce and not yet mature. Present-day, FOSS tools that rely on interoperability specifications resemble meta-tagging interfaces rather than authoring tools. In fact, Sayago [11] noted that the set of FOSS tools, created in compliance with IMS QTI specifications, tends to achieve low usability scores, mainly for not abstracting the specifications enough from their users. In contrast, a quick overview of commercial e-learning authoring and CDP management tools heavily suggests a much higher usability than FOSS.

In conclusion, any proper selection criteria of FOSS components must address both interoperability and usability simultaneously, since low usability of e-learning systems is among the principal reasons of failure due to the elevated drop-out rate that they can engender [8].

5.2 QAed for Managing Competences and CDPs

Interoperability and usability need not to be conflicting in e-learning applications. Sayago et al. have developed an authoring tool called QAed [11] to demonstrate how specifications can be implemented under a user-friendly interface. The QAed tool facilitates the creation and management of assessment repositories. It is based on a simplified version of IMS QTI specifications, known as QTI-Lite. This tool was produced for the purpose of creating an e-learning framework, and relies on a set of QTI-Lite Java libraries to provide an IMS specifications-compliant functionality for the construction of assessment contents. On the other hand, the QAed's interface hides the specifications and related technical terminologies from the authors, and provides additional structures and functionalities related to their needs.

The QAed tool is currently a standalone application and undergoing efforts are transforming it to an open-source plug-in for service oriented architectures. Since we expect that it will be fairly straightforward to map our future models of competences and CDPs into IMS format specifications, the QAed tool represents a strong candidate to handle the management of repositories of competences and CDPs.

6 Conclusions

The aim of the TenCompetence project is to provide a generic architecture for a European learning network, to develop a new form of education delivery that goes beyond course and program centric models, and to envision a learner-centred and learner-controlled model of lifelong learning.

The components introduced in this paper should ensure that the learner control does not come with the cost of extra responsibilities with regard to finding their own peers, discovering knowledge resources, or creating their own customized programmes; the system should provide adequate means and adequate feedback for these meta-learning activities. The concepts are largely dependent on the learners' input, which includes keeping their e-portfolios up-to-date, participating in the various communications, and rating the available resources. In order to stimulate participants to carry out these activities, incentive mechanisms could be applied to render the learner's experience more profitable, pleasant and joyful.

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Matchmaking in Learning Networks: A System to Support Knowledge Sharing

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Abstract

In this paper we describe a system that matches learners with complementary content expertise as a reaction to a learner-request for knowledge sharing. It works through the formation of ad hoc, transient communities that exist for a limited period of time and stimulate learners to socially interact. The matchmaking system consists of a request module, a population module and a community module, all supported by a database that contains learning content, learner information and output of the system. The request module allows the learner to type in a request, the time span in which an answer should be provided and the content it is related to. The population module selects suitable learners to populate the community by determining their [1] content competency, [2] sharing competency, [3] eligibility and [4] availability. MOODLE is used to host the community. Experiments are planned to establish the feasibility of the overall design.

Keywords: knowledge sharing, learning communities, social interaction

1. Introduction

In its broadest form, learning networks are defined as the experiences of students and teachers with the use of computers in learning [1]. More specifically, learning networks are considered to "use computer-mediated communication to support the delivery of courses in which anytime, anywhere access to interactions among the students and between the instructor/facilitator and the students are key elements" [2 (p. 1); 3]. In our view a Learning Network (LN) can be set apart from the learning networks defined earlier in that they are self-organizing and give rise to lifelong learning [4; 5]. This does not mean that social interaction and learning is supposed magically to occur. Rather it emphasizes that the social structures that are conducive to or even needed for learning, emerge on top of a responsive, sophisticated, yet non-imposing technical infrastructure that allows the Learning Network Users (LNUs) to develop their own preferred modes of interaction, and to guide self-organization.

In LNs, LNUs are stimulated to create their own learning activities, build their own learning plans, and share their learning activities and their plans with peers and institutions. This self-directedness, however, may easily turn into isolation. LNUs who do not feel a sense of belonging with respect to a particular LN, are unlikely to interact with their peers, i.e. are unlikely to experience even a modicum of social interaction. Similarly, LNUs who do not feel engaged or committed are less likely to initiate an interaction with others, decreasing the sociability of the network as a whole. All this could be problematic since research shows that individual success or failure on a learning activity depends on the extent to which learners perceive themselves to be outsiders or insiders of a network [6]. So, without a technical infrastructure that invites social interaction and that guides self-organization within a LN, problems will arise that could hamper the academic achievement of its users.

In this paper we describe a system that matches LNUs with complementary content expertise. It works through the formation of so called *ad hoc*, *transient* communities. They are communities that (1) exist for a limited period of time, (2) specifically to fulfill the goal of knowledge sharing. This system supports the social embedding of LNUs in the LN and stimulates the LNUs to socially interact by sharing knowledge.

2. Theoretical basis of the matchmaking system for knowledge sharing

A survey of the literature [see 7] yields three important conditions that should be met to enable knowledge sharing and learning in communities; we will summarise them here. First, to facilitate cooperation or collaboration in a community, clear boundaries and a clear set of rules that can be monitored and sanctioned within the community are required (the *boundary* condition) [8]. Furthermore, to assure the liveliness of a community, it should be populated with a heterogeneous group consisting of, for example, veterans and newbies or lurkers and posters (the *heterogeneity* condition) [9]. Also, for the social embedding of LNUs, one should establish recognizability of users, a historical record of actions, and continuity of contact (the *accountability* condition) [10].

2.1 The boundary condition

To meet the *boundary* condition, ad hoc, transient communities should have a clear goal. Usually, this is triggered by a request of a LNU, for example, a content related question. The goal forms the incentive for the process of knowledge sharing. Indirectly this goal strongly influences the amount of social interaction during knowledge sharing within the community. Clearly, a goal that can be reached by only one correct solution will elicit less social interaction than a goal that can be reached through various solutions. Different interaction-structures can be implemented to mediate the effects of a goal on the social interaction. For example, if the goal of the ad hoc, transient community can be reached by a limited number of solutions then a peer-tutoring structure could stimulate social interaction. King, Staffieri, and Adelgais [11] advocate a three-step structure that consists of communication guidelines [i.e., listening, encouraging and giving feedback], an explanation procedure (i.e., the TEL WHY-procedure; telling in one's own words, explaining why and how, and linking of content), and questioning guidelines (e.g., asking comprehension questions or thinking questions). Other examples of structuring interaction within groups are "...'Group Investigation' [12], 'Student Teams Achievement Division' [13], 'Jigsaw' [14; 15], 'Structural Approach' [16] (each structure is a scenario to teach specific skills and, although not likewise articulated, it is implicitly assumed that no situation is identical), 'Progressive Inquiry' [17], the use of scripts [18; 19], scenarios that prescribe collaboration activity [20], feedback rules or requirements of a minimum degree of contributions to a discussion [21; 3]." [22; p.33]. From our perspective, 'high-structuring' methods such as peer-tutoring or Jigsaw are most suitable for goals that can be reached by a limited number of solutions because they guarantee a minimum amount of social interaction. 'Low-structuring' methods such as Progressive Inquiry, however, are most suitable for goals that can be reached by various solutions because these methods support rather than elicit social interaction (e.g. negotiation, argumentation) which is believed to be necessary under these circumstances.

2.2 The heterogeneity condition

To guarantee that the *heterogeneity* condition is met each ad hoc, transient community consists of a mix of LNUs with complementary expertise, all related to the goal of the community. So if, for example, 'answering a content related question' is the goal of the ad hoc, transient community, it should consist of LNUs with different levels of expertise related to the content-question since heterogeneity in levels of expertise can have differential effects on learning. Although King and colleagues [11] found that peer-tutors do not necessarily have to be more competent or more knowledgeable than their tutee counterparts, a study of Hinds, Patterson, and Pfeffer [23] indicates that tutors equal in competence convey qualitatively different knowledge than more distant tutors. The near tutors - those who are similar to their tutees in expertise level - use more concrete statements during their interactions with the tutee. In contrast, the distant tutors - those with a higher level of expertise - convey more abstract and advanced concepts. Heterogeneity in level of expertise between LNUs thus leads to a wide spectrum of knowledge shared in the community.

2.3 The accountability condition

The recognisability of users is assured by forbidding the use of aliases such as screen names; this seems a reasonable demand to make in the context of a network devoted to learning. If one does not want to be this strict, users that go by a pseudonym should adopt one and only one persistent pseudonym, i.e. a singly pseudonym they keep throughout their membership of the LN and use in all interactions.

A historical record of user activities is maintained by logging all LNU-activities. The ones most significant for knowledge sharing - activities that reflect content competency and sharing competency - become part of the LNU's e-portfolio. Content competency reflects the LNU's mastery of the content within the LN. Hereto, the e-portfolio contains the products that resulted from the learning activities of a LNU (i.e., papers, reports, assessments). Sharing competency refers to the ability of a LNU to satisfactorily support peers during a process of knowledge sharing. This information could be acquired by letting LNUs rate each other's performance in the ad hoc, transient communities. The e-portfolio also incorporates this information. To enhance individual accountability [13], both content and sharing competency of a LNU is made visible to the members of a particular ad hoc, transient community (there seems to be no reason to stigmatize a person at this stage by making it always available within the entire LN). For the same reason, rating should not be anonymous, at most singularly and persistently pseudonymous.

Continuity of contact during the ad hoc community's short lifetime is guaranteed by the interaction-structure that is implemented in them (see the boundary condition). Furthermore, these communities continuously surface in the LN to serve different purposes and although they continuously change with regard to composition, LNUs are likely to meet again.

3. The matchmaking system for knowledge sharing

The primary goal of the matchmaking system is to identify matching LNUs so as to populate the ad hoc, transient communities as a reaction to a particular LNU-request for knowledge sharing. It should be a web accessible [for easy access] and modular (for easy extensibility) system. For the latter reason, open source systems are preferable. The system consists of three functional units: the request module, the population module and the community module, all supported by a database. The database contains learning content (e.g., documents) organized in courses, LNU information (e.g., completed courses, current courses, activities, calendar) and output of, among others things, the matchmaking system.

The following standards are adopted in the matchmaking system: Learning Information Package (LIP) that assures the interoperability of student information between e-learning environments and Content Packaging (CP) that guarantees the interoperability of content information between e-learning environments. When possible, Learning Design (LD) that standardizes learning 'workflows' will be adopted to make sure that the knowledge sharing process is independent from the e-learning environment.

3.1 The request module

Modular Object-Orientated Dynamic Learning Environment (MOODLE; http://www.moodle.org) is used for the request module in which each LNU can pose his or her request[s]. The request module interface allows the LNU to type in, for example, a content related question, the time span in which an answer should be provided and the content the question is related to. These data are stored in the database. Simultaneously, MOODLE activates another system that uses Latent Semantic Analysis (LSA) to map the content question on the available documents in the database [24]. The LSA-system outputs (1) correlations between the question and (fragments of) the documents in the database and (2) text fragments related to the content question. These data are also stored in the database for later use.

3.2 The population module

PHP is used to program the population module that selects suitable LNUs to populate the ad hoc, transient community. This selection process consists of four steps: [1] determine the content competency of a LNU, [2] determine the sharing competency of a LNU, [3] assure the heterogeneity of the community population and [4] determine the availability of the LNU.

Determine content competency. To determine the content competency of LNUs the most relevant documents with regard to the question are selected from the database. The document selection conditions – to wit lowest allowable correlation and maximum selectable number of documents - are set beforehand. It is determined to which course, occasionally courses, each document belongs. In addition, based on the question-document correlations provided by the LSA-system, the question-course correlation is determined. The question-course correlation either equals the maximum question-document correlation of belonging documents or the mean question-document correlation of belonging documents. From the database it is retrieved whether [1] a LNU completed each relevant course, [2] the time it took the LNU to complete each relevant course and [3] how long ago each relevant course has been completed by the LNU. These data yield a measure that indicates a LNUs course competency. For each LNU this course competency is weighed by the question-course correlation which yields the content competency.

Determine sharing competency. The sharing competency is related to the expertise of a LNU as a contributor in ad hoc, transient communities and/or to a peer-rating of his/her contribution quality. The weight of these measures is set beforehand. The sharing expertise is expressed by the relative number of contributions made by a LNU. It is calculated by dividing the number of contributions a LNU makes in an ad hoc, transient community by the total number of contributions made by all LNUs in this community. At the break-up of a community each participating LNU rates the quality of the other LNUs' contributions. A weighted combination of sharing expertise as well as the peer-rating expresses the sharing competency.

Assure heterogeneity of the community population. The heterogeneity of the community is assured by comparing the portfolio [i.e., completed and not completed courses] of the LNU that submitted the request to the other LNUs. From the database it is retrieved (1) which courses are and are not completed by the LNUs and (2) which courses are relevant for the request. LNUs who did not complete any relevant course are not taken into consideration (i.e., they are set to zero). For LNUs who did complete any of the relevant courses, the similarity between their portfolio (i.e., completed and not completed courses) and the portfolio of the requester is calculated. The more similar the portfolios of two LNUs, the more equal their level of expertise and vice versa.

Determine the availability of the LNU. The availability is related to the past contributor load of a LNU in ad hoc, transient communities and/or to the available time of a LNU. The weight of these measures is set beforehand. The past contributor load is expressed by a combination of the relative number of communities a LNU has been involved in and the peer-rating of his/her contributions in these communities. The available time of a LNU is retrieved from the database and compared to the time span in which a contribution should be provided (i.e., input from the request module). A weighted combination of the past contributor load and available time expresses the availability of a LNU.

Based on the four measures described above, suitable LNUs can be selected to populate the ad hoc, transient communities. At least two LNUs are selected: the requester, and one or more LNUs to obtain knowledge from. Although, common sense tells us that the group size of the community should not be too large (about 5 LNUs?) the cooperative learning literature does not provide specific guidelines on how to determine the optimal group size. Most of the time no distinction is made between interaction patterns for dyads, small groups (three to six members), and large groups (seven or more members) although the interaction patterns may differ [25]. However, since the number of inactive group members (i.e. lurkers) increases as group size increases (because of the lessened individual accountability of the group members), the effect of the increased group size on the interaction patterns of the active members may indeed be negligible [8].

3.3 The community module

MOODLE is used to host the community. MOODLE is a full-blown virtual learning environment of which for the present purposes only the communication tools are relevant (the request module is a purpose built MOODLE extension). MOODLE offers both a forum and a wiki. The strength of a forum is that it enables its users to discuss specific topics, organized in threads. So each thread covers a separate topic and the threads usually branch off in subtopics. The history of the discussion can be traced by following a thread from origin to end. A wiki enables users to collaboratively work on a specific document. Wikis allow one to follow the history of the document because they maintain a history of the edits, including their time and author.

So both tools thus can be used to trace back the history of a discussion. For the present system, however, the collaborative nature of the wiki is an important asset. Also, the opposing opinions themselves are less important that the product that resulted from them. LNUs willing to share their knowledge could do so through a forum and then would each have to write up an answer to the question asked. Subsequently, it is up to the requester to make sense of all the answers and select what suits him or her best. Interaction with the LNUs providing the answer can only be done through commenting in the threads. In a wiki, however, the LNUs answering the question comment by editing each others answers. Thus they will arrive at the best answer as a collective. The LNU asking the question now does not have to filter the disparate information offered in the various threads, but can focus on one single answer. He or she can still comment, but it is also possible to rephrase the original question and even reformulate the answer in order to find out whether it was understood properly. So a wiki is to be preferred because the filtering of the information that is shared with the person who asked the question is done by those who share themselves. And clearly, they are in a better position to do so than the person asking the question.

4. Discussion

We have discussed the design of a system for asymmetrical knowledge sharing in a LN. The specifics of the design were based upon a careful consideration of the extant literature and were set out to meet the boundary condition, the heterogeneity condition and the accountability condition to assure the thriving of the ad hoc, transient communities.

Experiments are planned to establish the feasibility of the overall design. Our first experiments will focus on peer tutoring as one specific kind of knowledge sharing (the boundary condition): "Does a peer-tutoring structure fit the knowledge sharing goal 'answering a content related question'?" and "Does a peer-tutoring structure put the knowledge sharing process on a higher plane?". Subsequently, we will take a closer look at the composition of the ad hoc, transient community to facilitate knowledge sharing (the heterogeneity condition): "What is the optimal group size for an ad hoc, transient community?" and "Does a mix of community members with different levels of expertise indeed lead to a wide spectrum of knowledge shared by the community?". Next, experiments will be carried out that focus on learner-representations in the LN (the accountability condition): "How do we guarantee the social presence of LNUs in the LN?" and "Does an e-portfolio that contains the history of content competency and sharing competency provide enough information to assure accountability?".

The results of these experiments will allow us both to optimize the present infrastructure and to inform our considerations of how to use the infrastructure for other, more generalized knowledge sharing activities.

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Sharing personal knowledge over the Semantic Web

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Distributed decision support, Semantic Web, Knowledge representation, Networks of Practice

Abstract

Every day humans solve a lot of common tasks and find out a lot of similar knowledge. In common sense sharing this knowledge could save them efforts and improve their decisions. In the global community of human beings there exist subcommunities of persons oriented to specific problems. These communities develop knowledge in time and share this knowledge to achieve better decision making. This paper discuss the possibilities of developing and investigating personal knowledge sharing software applications. We define the main parameters of such application, the methodology used to describe and share knowledge, create an inceptive model of the application and analyze the possible technologies and problem fields to implement such system.

1. Introduction

Every day humans do a lot of similar stuff, solve a lot of common tasks and find out a lot of similar knowledge. The problems solved could be community-oriented like arranging a common space or creating a common document, or person oriented problems like planning a weekend or tuning a software application; business-oriented like an insurance agent support system or non-profit based like a mutual aid forum. We state that the current situation in the field of computer network technologies and social networks development is bringing up the need of such applications in the limelight.

In common sense sharing this knowledge could save people efforts and improve their decisions. In the global community of human beings there exist subcommunities of persons oriented to specific problems, that develop knowledge in time and that share this knowledge to achieve better decision making. What is common within knowledge development and sharing is that the "*Research has consistently shown that social relationships are important to the ability of individuals to gather knowledge and to perform their work and that the creation of knowledge is innately a social process among individuals*" [1, p. 2]. These communities were investigated in the early 90' s by Lave and Wenger [2] and called *Communities of Practice* (often abbreviated as CoPs). They described the Community of Practice as "... *a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping CoPs*". Later John Seely-Brown and Paul Duguid [3] developed the concept of *Networks of Practice* (often abbreviated as NoPs).

The later work in the area of knowledge sharing and representation is concentrated around the term *ontology*. Ontologies are "*specifications of conceptualizations*" [4]. In 1998 Tim Berners-Lee [5] presented his view of a new network of shared knowledge calls Semantic Web, built over the current Web, that should enable the AI applications to share knowledge in the most powerful way currently provided by computer technologies.

2. Characteristics of the examined networks

Specifics of the networks of practice

Lave and Wenger [2] use the term *Legitimate Peripheral Participation* (LPP) to describe the process of interaction between the actors in a NoP. It refers to the complicated process of joining, using and contributing to a NoP and turning the newcomer into an experienced member of the community.

The initial research of the local CoPs showed, that the face-to-face knowledge exchange strongly depends on the stable ties, co-location, agents similarity and the prior relationships [6]. With the process of economic globalization and company internationalization the distributed and electronically organized CoPs came in front [7]. Bourhis, Dube and Jacob [8] defined Electronic CoP as "*a CoP whose members use information and communication technology as their primary mode of interaction. ...Being virtual does not exclude the use of face-to-face meetings, but several factors such as geographical dispersion and busy schedules, make communicating through ICT much more efficient.*". According to Landqvist and Teigland [9] the heterogeneity of the actors and resources and the quality of the social ties in the NoP have significant role in the process of knowledge development.

Usually the knowledge shared in a community of practice is not formalized, sometimes it even could not be formalized, it is mostly "*an unrecognized resource held in the minds of workers*" [7]. This knowledge is usually called *tacit knowledge*, in opposite to the *explicit knowledge*, which is usually formalized, oriented to a specific domain and therefore – easy to process by machines. As Edvinsson and Malone [10] say "*Tacit knowledge is highly personal and hard to formalize, making it difficult to communicate or share with others"*.

Informal description of the examined networks

Not every NoP could fit in a formal model and not every NoP could be spread over a computer network. So we define a subset of NoPs could take advantage from the computer network shared knowledge. These NoPs should fit the above description – they should contain of a group of people that solve a similar problem, every person works to produce a (part of) problem decision. The problem decision is based on knowledge about the concrete problem field. So we formalize those features of the NoP, that we consider to stay in the foundation of the successful knowledge sharing community based on a computer network:

1* *Users have basic computer access and literacy.* Even the best software application could not help people that do not want or can not use it at all.

2* *Users are autonomous both in acting and evaluating the results.* In the common case the desired decision could be different for the different persons or subgroups of persons, but they share the same problem domain, so they could share a domain-specific knowledge to help the problem solving.

3* *Users like each other. Increasing the quantity of the knowledge shared will increase the benefit from the network.* We do not consider cases where the users have contrary interests. Of course in a bad system more knowledge could make things worse, but we want to create the best system anyway.

4* *Users like each other in a different way.* In a NoP there could be very complicated relations between the persons. We would like to describe these relations as far as they affect the knowledge sharing and using process.

5* *The knowledge domain is a subject of a formal description, but the knowledge shared could be incomplete.* This does not mean that the knowledge shared should be *well* described in a formal language, but this means that the users should be able to share *some* formally described knowledge about the problem field.

6* *Computation technology...* We go further than Dube at Al. and define our NoP as *an electronic NoP whose members use computation technology for knowledge exchange and development*. We reckon the current electronic NoPs do not take the best advantage of the current computation technologies and suggest how to change this.

3. Software application model

Below we define mathematical model of an application that could be used to share person-specific knowledge on a common tasks and to take advantage of the share by automated development and usage of new knowledge. Such applications do not exist yet, and, as far as we know, there have not been neither developed, nor defined any at all. The model we define conforms the features 1* to 6* and therefore could be applied to any problem field that fits in this features.

According to 5* we have formal description of the problem and the related knowledge and this description is presented in a machine-readable language. Every problem to solve and every problem decision will be a series of words in the underlying language. Hence, we can define a set of answers **A** and a set of questions **Q**, and for every question from **Q** we will have an answer from **A**. To be able to detect errors, we accept some distance defined in **A**, in the worst case it could be the Hamming distance [11]. Lets have an electronic NoP of *k* users $\mathbf{U} = \{U_1, ..., U_k\}$, that take decisions to reply to a question $q \in \mathbf{Q}$ with an answer $a \in \mathbf{A}$ (2*). Because of computer access (1*) and computational power (6*), we can set a software agent in front of each user, that listens to the corresponding user's decisions and to the other users' decisions and tries to reveal the perfect decision for the corresponding user. So we have *k* functions $\mathbf{u} = \{u_1, ..., u_k \mid u_i : \mathbf{Q} \to \mathbf{A}\}$, which describe the ideal behavior of our agent. Users provide each other information of their own knowledge (3*), so our agent knows parts of these functions, say $\mathbf{u'} = \{u_1', ..., u_k' \mid u_i' \subset u_i\}$.

Also, every user provides his agent with problem specific knowledge (3*, 5*). This knowledge we define as transformations $t : \mathbf{O} \to \mathbf{O}$, where $\mathbf{O} \subset \mathbf{A} \times \mathbf{Q}$. We accept the user executes these transformations in the process of transforming the question *q* to an answer *a*. Note, that we can describe this way knowledge, which is not explicitly perceived as a transformation by the user. For example the rule **if *condition* then *action*** could be present as a transformation of the system state before the rule execution to the system state after the rule execution. So our agent needs to find an appropriate series of transformations $t_1^q, ..., t_n^q$, such that $t_1^q:\mathbf{Q} \to \mathbf{O}$, $t_n^q:\mathbf{O} \to \mathbf{A}$ and $t_n^q(t_{n-1}^q(...t_1^q(q)))=u(q)$ for as many *q* as possible (6*). Basically our agent should find out a procedure *P*, that will provide this series for a specified *q*. The transformations are kept in the knowledge repositories of the underlying user and the other users. For evaluation of the result is used *u'* function which we know. We know the knowledge shared is unreliable or incomplete (5*). Thus we nominate a factor of trust of transformation FTT : $\mathbf{T} \times \mathbf{U} \to [0,1]$, where $\mathbf{T}=\{t \mid t : \mathbf{O} \to \mathbf{O}\}$, which measures the trust every user agent gives to a specific transformation.

We know there are complicated relationships between the users (4*). These relationships are based on the social ties, and to describe them well is not the subject of this study. We are interested only in the degree of the usability of one's knowledge in the repository of another user. So, we define a metric on the set of our user agents **U**, $m : \mathbf{U} \times \mathbf{U} \to [0, 1]$. This metric is used to model a simple relation between users (4*), $m(U_i, U_j) > m(U_i, U_l)$ mean that the knowledge defined by user *j* is more useful for the user *i* than the knowledge from user *l*. Every user *i* defines the values for $m(U_i, U_k)$ himself (2*). Thus the value $m(U_i, U_j)$ measures how much user U_i *trusts* user U_j, or how much the agent of the user U_i relies on the knowledge received from the user U_j. On later phases we could use a set of metrics to represent better the complicated relationships between users. Since users are supposed to give the best trust to their own judgments, we consider $m(U_i, U_i) = 1$.

We define the factor of trust of shared transformation FTST: $\mathbf{T} \times \mathbf{U} \to [0, 1]$ as the arithmetic average $\mathrm{FTST}(t, U) = \sum \mathrm{FTT}(t, U_i) m(U, U_i)/|\mathbf{U}|$ for $U \in \mathbf{U}$. This measures the trust of a transformation for a specific user according the set of the available users. Closer relationships between users and bigger $\mathrm{FTT}(t_i, U_j)$ lead to bigger FTST(*t*, *U*). Bigger FTST(*t*, *U*) means user U thinks transformation *t* is more likely to draw us nearer to a good result. We also define a factor of trust of shared series of transformations $\mathrm{FTSS}(\boldsymbol{t_i}, U) = \prod \mathrm{FTST}(t, U) \mid \boldsymbol{t_i} = (t_1, ..., t_n)$, that will define the trust on a series of transformation according to the available knowledge. The selected function *product* gives more value to the individual trust of a concrete transformation than, for example, the simple *addition*. The procedure *P* will create a set of possible transformation series $\boldsymbol{t_1}, ..., \boldsymbol{t_n}$ ordered by $\mathrm{FTSS}(\boldsymbol{t_i})$.

Knowledge flow

The system that implements the above model contains the following components:

1. An *external knowledge repository*. It will contain the trust distances to the other agents as defined by the user, the knowledge received from the other agents and parts of the *u'* functions of the related agents.
2. A *local knowledge repository*. Contains a set of transformations t_i and the values of

FTST(t_i).

3. A *calculation subsystem*. It will take care to support the most appropriate *P* procedure according to the current state of the knowledge repository.
4. An *user agent*. It will take care about the translating user knowledge in a formal language and vice-versa. Obviously the concrete implementation strongly depends on the problem area.

There are two main procedures – updating knowledge repository and generating transformation chains:

A knowledge repository update could be caused by update of any data in the external knowledge repository. In this case the set of transformations and the FTST values should be refreshed.

The answer generation procedure starts with question from the user. The procedure *P* generated by the calculation subsystem is called to find the best available transformation chains and the result is sent back to the user agent. The agent chooses its own way to present the result to the user and to get the corresponding error.

Evaluation of the results

As we do not know about similar projects, we can not compare the results of the system with the results of already existing ones. But we still can get a judge of its usefulness based on the errors in the answers from the user. The user agent will provide an evaluation of the error for every result generated by the calculation subsystem.

4. Technologies

It is is possible to implement the software application model described above with the existing software technologies. Of course the choice of a concrete technology depends on the problem field, knowledge described, resources available, but we can still give some directions in choosing the appropriate framework. "*The Semantic Web* (SW) *provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries"* [12]. This is how the information of the SW itself is created: "*different communities of practice develop independently, bottom up, and then can connect link by link, like patches sewn together at the edges"* [13]. So we stand on this framework to describe tools and technologies to implement the desired application.

SW suggests the OWL (Web Ontology Language) language for knowledge description. This language is designed to support distributed, versioned and inconsistent ontologies over the Web. For a concrete system we can describe an ontology in this language and base further knowledge development on it. The ontology must be common for all users and must well respond to their view of the problem field. This itself is a task of creating a community good based on the community shared knowledge, but we will pass along it for now and will accept there already exists an ontology that is good enough for all users to share knowledge trough it. Because we want be able to deduce new knowledge from the already shared, we will limit the language used to OWL DL.

Defining transformations in the terms of the SW means to define procedures using rules based on the ontology graph. There are various attempts to define language for rules description around the OWL, but the most common choice it the SWRL [14] as long as it is currently a submission from W3C.

We will also need a common ontology to define the common characteristics of the models, like the metrics of the *trust* between users, agent properties like location, protocol supported, etc.

To exchange knowledge in the form of ontologies we could use simply access to the ontology description text trough the Web. So the simplest way to retrieve the ontology content is the HTTP. In order to improve the communication and synchronization between the different agents we could use Web Services or even Semantic Web Services[15].

The inference of knowledge and its potentialities will be based on the selected representation method. Thus we are limited by OWL DL and SWRL in the sphere of the description logics and the first order predicate logics. The inferred knowledge will be presented in the way the asserted knowledge is. There are various reasoners for OWL DL and SWRL, so implementors will be able to pick the one that best fits their needs.

5. Conclusions and future development

Based on the above arguments we can try to implement systems that share and use personal knowledge. There are no systems that implement the model described above, but there exist a lot of appropriate problem fields, like GUI translation communities, local neighborhood communities, activity planning communities, etc. These systems will fill a niche in the field of software applications and will make the computers more useful for personal use. Still, there is much more to do in the theoretical field. We will underline some problems we consider as important for future development.

Currently we do not take in account the difference between person-oriented and community-oriented tasks. Solving these two types of problems should be based on a specific types of knowledge. Understanding the knowledge type specifics and extending the above model could help in development of concrete systems of the corresponding type.

Any implementation of the model will need a common ontology accepted by all the members of the community. The creation of this ontology is a community-oriented personal knowledge sharing problem itself, which could be based on a prime ontology itself. It will be useful to define and implement a system or a subsystem as a decision of the problem. Currently the SW framework does not support an explicit definition of fuzzy and even inconsistent ontologies. In our system the knowledge will be not only distributed, but also uncertain, which means the global knowledge base and eventually the basic common ontology will contain fuzzy knowledge. Therefore an OWL extension will be useful for description of this type of knowledge.

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Campus Canada Records of Learning: Secure validation of competence assertions

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Abstract
Campus Canada is a consortium of post-secondary institutions and workplace trainers that promotes lifelong learning through the articulation of workplace and other experiential learning for academic credit. This paper describes the recent redevelopment of the Record of Learning component of the Campus Canada's ePortfolio System. In matching the academic members' desires for provision of secure e-transcripts with learners' desires for validation of educational assertions, the RoL provides a win-win lever for an expanded e-portfolio service without creating clerical log jams. The new RoL system paves the way for web services interoperability between registrar services and for automated creation of secure Records of Learning by workplace trainers.

Keywords: records of learning, assertions of competence, interoperability, security

Introduction

Campus Canada is a not-for-profit corporation established in 2002 with a mandate to remove the barriers to post-secondary education by providing an enhanced range of educational programs and support services to the adult learner. It was created as a result of a Request for Proposals issued by the Government of Canada (Department of Industry Canada) in 2000. The purpose of the RFP was to identify post-secondary institutions prepared to provide various academic services such as Prior Learning Assessment and Recognition, Foreign Credential Recognition, Assessment of Workplace Training and credit banking services.

Through Campus Canada, agreements can be brokered for the recognition of workplace training and experience that paves the way for entry into post-secondary academic programs. For example, police officers completing a regimen of workplace training courses might find that this articulates into a degree program in criminology; finance clerks might earn partial credit towards a college diploma in accounting. The laddering of workplace training into academic programs provides a three-way win: workers gain improved access to life-long learning opportunities, employers can encourage employees to extend their professional skills and knowledge beyond the in-house training opportunities, and academic institutions can market programs tailored to the needs of specific occupations.

While each member institution is autonomous, all members share in a common goal of supporting all levels and types of learners from those returning to formal study after a substantial break through to lifelong learners. Campus Canada's original infrastructure plan included central registration and payment portal, student services such as self-assessment tools and advising, and a central student record of learning. This paper describes redevelopment of a secure Record of Learning System based upon validation of learner assertions of individual credentials and competencies. The potential extension of this interoperability framework to other institutional services is also discussed.

Records of Learning

Most academic organizations and guilds keep some form or written information about the achievements of their community. Indeed, the engineering profession in Europe has recently developed the European Record of Achievement for Professional in the Engineering Profession (EuroRecord). This ePortfolio tool is aimed at one profession and its goal is to provide "in a single tool, a comprehensive record of professional learning, transparent across markets" [1]

In New Zealand a more comprehensive record of learning is found in the National Qualifications Framework (NQF) (see www.nzqa.govt.nz). The NQF is supported by the government, industry and regulatory bodies. Learners pay a modest fee for both registration and credits earned. The NQF provides 18,000 nationally agreed upon standards from basic trades training and secondary education through to postgraduate degrees to which assessment is carried out by accredited organizations. This requires the physical presence of the applicant [2]. Yearly or upon request, the NOF sends the learner a Record of Learning [3].

Campus Canada developed an e-Portfolio site to enable workplace learners to collate information about their personal skills, knowledge, experience and credentials and have these validated. The ePortfolio can also serve as a planning aid for potential immigrants to Canada [4]. Campus Canada's RoL was not restricted to any specific trade or profession, and while its current implementation lacks the ubiquity of the New Zealand's nation-wide system, it has potential for greater reach as all transactions with the RoL can be conducted via internet.

Pilot RoL Evaluation

As with many e-portfolio systems, Campus Canada's e-portfolio web site (http://campuscanada.ca/new/index.php) provides three functional components: an archive of artifacts, a Record of Learning, and the ability to generate a number of unique "views" or custom web pages that provide a selection of information for, say, a potential employment opportunity. Unique in the design of the Campus Canada RoL was the notion of validity – a learner could request that Campus Canada validate the contents of their RoL, and that the "certified true" RoL would then be trusted by the Campus Canada community thus saving redundancy of screening efforts when the learner made subsequent application to multiple programs or employment opportunities. While conceptually popular, validation was labour-intensive, involving clerks contacting a wide variety of schools and former employers. A further complication was that once validated, the RoL was a "locked document" and another mechanism would be needed to amend it as the learner acquired future credentials. Because validation can difficult if it involves other languages or countries, the RoL system would also need to work with foreign credential evaluation agencies such as the International Credential Evaluation Service (www.bcit.ca/ices).

Evaluation of the pilot RoL suggested that validation needed to have less potential for clerical bottlenecks and more flexible in allowing learners to decide which credentials they wanted validated. It had to be amendable so that learners could easily add new credentials as they were earned. Automation of the validation process would be necessary to enable scalability as the RoL became widely adopted [5].

A second factor leading to re-development were concerns by academic registrars that additional clerical resources were simply not available, and there was a pragmatic need to constrain the RoL validation within the current policies, practices and workload related to the issuing of academic transcripts. The registrars were supportive of placing e-transcripts in the RoL if a high level of security, audit trail and the ability to revoke problem documents were ensured.

Assertions of credentials and competencies

The first design decision was to break the whole list RoL into a collection of separate "assertions". An assertion is a statement claiming the completion of a course, the acquisition of a diploma or other qualification of skill or knowledge competence. Since each assertion would identify the issuing authority, each assertion could be sent to the issuing authority with a request to validate the information by signing and returning an electronic (PDF) document. If one or several validations were not possible this would neither delay nor reject the validation of assertions that were more easily validated. The signed document (PDF) would be kept on file to provide an audit trail of validated assertions.

The next step was to automate as much of the workflow as possible for processing requests for validation of assertions. This devolved three workflow instances for organizations that belonged to Campus Canada:

a) Validation via institutional registrars
b) Validation via credential evaluation agencies, and
c) Validation via workplace training managers.

As the official keepers of academic records, Registrars have institutional responsibility to provide transcripts to students. Key criteria were:

d) registrars could provide complete transcripts as records of learning,
e) the protection of personal information legislation demanded the same standard of care was met in verifying the identity of the person to whom the information was released,
f) that there was no possibility that transcripts could be modified,
g) that there was a mechanism for revoking transcripts should administrative adjustment be required or fraud be discovered, and
h) registrars noted they had the capability to generate transcripts in PDF form.

In Canada credential evaluation agencies assess foreign degrees and diplomas and issue an opinion as to their comparable equivalence to Canadian credentials. The instrument of validation for this group would be a digitally signed copy of the opinion in PDF format.

Workplace trainers would interact with the RoL system in two ways – either by digitally signing a copy of a single assertion or, if a member of Campus Canada, by uploading validated assertions directly to their employees' RoLs upon the successful completion of a training session. Of course, the latter would require prior arrangement to ensure trainees had e-portfolios and had agreed to permit direct deposits into their record of learning.

The instrument of validation converged on Adobe's PDF format documents as this was a readily accepted standard for signing documents and a wide variety of methods for digitally affixing signatures and tamper-proofing the document were available. Since some members of Campus Canada already use Adobe software to sign PDF files, we configured the RoL system to give them the option to continue with current practice, or to install a custom utility designed for this purpose. The utility also supports batch processing of multiple records.

Workflow

The RoL workflow begins when a learner creates an assertion of competence by completing a form on the Campus Canada e-portfolio web site and requesting validation from the accrediting institution. The request is held on the RoL web site, and an e-mail notifies the appropriate signing authority (usually a designated clerk in the Registrar's Office). The clerk logs into the secure RoL system and, in a certificate authenticated web transaction, downloads the assertion. Once learner information is checked, the clerk signs the assertion with their digital signature and uploads the supporting document, most likely an electronic transcript. A message field is available in the event that verification can not be made immediately (learners often have problems recalling their exact date or attendance, student number or even the name they were registered as a student). The supporting document is held in the Campus Canada site and can be accessed from the e-Portfolio view if a potential employer wishes to verify the validation.

Security

Campus Canada provides a central hub in a network of trusted peers. To protect personal information, all RoL transactions are encrypted using Public Key/Private Key methods. To ensure accountability, each designated institutional authority is issued with a personal digital certificate from Campus Canada to authenticate their identity and permissions. This certificate is used to sign PDF documents and thus every back-end transaction can be traced to the individual responsible. Once information is released to the learner's password-protected ePortfolio it is up to the learner to decide what they share in their views. As with conventional paper transcripts, learners are responsible for safeguarding access to information under their control.

Transaction logging and maintenance of signed PDF documents on the Campus Canada site provides an auditable trail for every validation requested and issued. If somehow a breach of procedure or a security lapse results in the issuing of inappropriate validations, the "chain of trust" enables the tracking and revoking of suspect validations. The clerk can return to the RoL web site, retrieve the record(s) in question and suspend the link between the assertion and the supporting document - a notice is automatically sent to the learner that the relevant assertion is no longer verifiable on the Campus Canada site.

Standards and Future Services

Examination of the current IMS specifications for ePortfolio interoperability [6] and particularly the results of the 2005 Plugfest indicated that although the specification was still in its formative stage, Campus Canada project could benefit by aligning several field names and XML document structures with the IMS recommendations. Registrars also expressed interest in compatibility with the SPEEDE/ ExPRESS data standard for e-transcripts that are exchanged inter-institutionally through an EDI crosswalk at the University of Texas Austin [7] An obvious extension of the secure e-transcript capability is the facilitation of peer-to-peer exchanges of e-transcripts without the need for an intermediating broker.

A second functionality for future development will be the ability of Campus Canada members to scan and certify "true digital copies" of paper certificates and diplomas issued by non-member institutions. Learners could use this support a wide variety of assertions from birth certificates to driver's licences. However, additional study is required to examine the policy implications of extending this web of trust to increasing opportunities for fraudulent documents, diplomas from unaccredited "diploma mills", or foreign documents without accompanying translations or verification that the bearer is indeed the person named on the document. As with any document, while it is up to each and every viewer to determine the extent of validation required for their particular purposes; each Campus Canada member also needs to determine which services they will offer in balancing their traditional roles with possibilities for a wide range of new services.

It is foreseen that corporate universities and other organization such as unions could use the e-portfolio / RoL system within their own environment as an enhancement to professional learning plans and, subject to local privacy legislation, access the backend data as a tool to meeting knowledge management requirements. After testing the RoL will be licensed as Open Source.

Conclusions

Campus Canada's new Record of Learning system is currently undergoing field-testing. Its key features are the use of learner assertions to generate validation requests, and the use of e-transcripts as the instrument of validation by institutional registrars. Valid Assertions are provided a unique link to supporting documents that can be used by viewers to verify the status of a validation. Credential evaluation agencies can also validate assertions by issuing a signed digital copy of assessment reports. Workplace trainers can either sign individual assertions, or if involved in large scale training efforts, can arrange for the batch uploading of certificates of completion via the secure web service.

Ultimately a key purpose of the Record of Learning is to enable the creation of articulation agreements between employers, occupational groups and education providers so that learners can track their readiness for laddered entry into academic programs offered by academic members and for opportunities for career advancement. Similarly learners could use views of information collated in their e-portfolios to substantiate applications for admission or challenge for credit. In occupation groups where there is a high degree of specialization or such as police or in banking where there is a great deal of workforce mobility, the record of learning may become the ideal way to keep track of one's life long accumulation of competencies and to enable workforce planning across large sectors of the economy.

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Frameworks of competence: common or specific?

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Abstract

Examples of what are known as frameworks of skill or competence suggest a range of requirements which might be met by such frameworks, for organisations, individuals and educational institutions. However, there are two opposing tendencies in framework development: towards different, context-specific frameworks and towards common, shared frameworks. The approach to resolving this, suggested here and prefigured in the JISC-funded SPWS project, is to make a clear distinction between the common and specific approaches, focusing agreement onto common frameworks for reference, while allowing divergence between specific frameworks for application and implementation. This may resolve the tension and allow both common and specific frameworks to flourish. Pointers are given for working towards this. Standards in the area need further development. E-learning tools, including e-portfolio systems, need to build in support for this two-component approach to frameworks of competence.

Keywords:
Skill, competence, frameworks, e-learning tools, e-portfolio systems

1 Introduction

The concept of frameworks of skill or competence has appeared in several contexts, serving several purposes. Stepping back from the actual examples, this paper looks at the way that the concept could meaningfully be used, and properly implemented. But to give initial substance to the discussion, a few examples of existing things which are, or might be, called frameworks of skill or competence will be indicated here.

To start with a practical example, this paper takes SFIA, the Skills Framework for the Information Age (http://www.sfia.org.uk/). It is used by several IT companies as a basis for managing many of their staff competences.

A second example is the Web-based personal development planning (PDP) system, LUSID (http://www.lusid.org.uk/) [1]. Amongst other functionality, LUSID offers people the chance to record and analyse their skills, particularly generic transferable skills. To do this, it has a configurable hierarchy of wider and narrower skill definitions. More about the skills framework aspect of LUSID can be found on JISC's e-Learning Framework site entry on the SPWS project (http://www.elframework.org/projects/spws), and related papers, e.g. [2].

A third example, general rather than specific, would be the many examples of sets of educational objectives, learning outcomes, items found in any curriculum or syllabus, or statements of what should be found there, typically within educational institutions. Many other examples of skills or competence frameworks can be found outside the confines of educational institutions.

On the basis of examples such as these, the purpose of this paper is to do as follows.

- To outline the various possible requirements in principle of a competence framework.
- To focus on one key issue: the tension between common and specific frameworks.
- To suggest strategies for resolving this issue and fulfilling the requirements.

Terminology: the terms "skill", "competence" and "competency" have been used in various diverse ways in the literature, and proposals for their definition and interrelationship have often conflicted with each other. While significant distinctions have been made for specific purposes, within the context of this paper the distinctions are less significant, because the frameworks discussed can be seen as covering all of these concepts at the same time. Thus, no specific or precise definitions are offered or referred to here.

2 Requirements for competence frameworks

The nature of appropriate scenarios of use of such frameworks is largely independent of the exact content of any particular competence framework.

In the corporate domain, the example of SFIA is illustrative. Their web site identifies it as providing "a common reference model for the identification of the skills needed to develop effective Information Systems (IS) making use of Information Communications Technologies (ICT). It is a simple and logical two-dimensional framework consisting of areas of work on one axis and levels of responsibility on the other." (http://www.sfia.org.uk/cgi-bin/wms.pl/296)

Frameworks like SFIA are intended be used "as a skills management tool within organisations that employ IT staff" (http://www.sfia.org.uk/cgi-bin/wms.pl/1002). This use could include playing a role in:

- assessment/assignment/recruitment, external or internal;
- skills gap analysis, and management of the corporate competency profile;
- developing and maintaining a business-oriented ontology.

For more personal use of competence frameworks, the UK definition of PDP (personal development planning) can be usefully referred to: "A structured and supported process undertaken by an individual to reflect upon their own learning, performance and achievement and to plan for their personal, educational and career development." (http://www.qaa.ac.uk/academicinfrastructure/progressFiles/archive/policystatement/). From this definition, possible uses of competence frameworks by individuals can readily be extrapolated, to aid in such purposes as:

- assessment of their own abilities/ skills/ competences/ knowledge;
- comparison with what is required for them to achieve their goals;
- action planning against externally defined competence objectives;
- development of their individual skills and competence, typically through courses of study, relevant experience, mentoring, guidance etc.

Requirements of educational institutions, related to competence frameworks, may include:

- selection of students;
- relating learning materials to learning objectives;
- management of learning outcomes;
- assessment;
- managing the ontology of their educational business.

In the UK, the academic community together, rather than individual institutions, led by the Quality Assurance Agency for Higher Education (QAA), have produced "subject benchmark statements", which "define what can be expected of a graduate in terms of the techniques and skills needed to develop understanding in the subject" (http://www.qaa.ac.uk/academicinfrastructure/benchmark/). Typically, subject benchmark statements include an informal description of the "knowledge, understanding and skills" associated with an academic subject. Ideally, this could be expected to relate to the requirements of potential employers of those graduates, but in practice there is little input from employers.

The existence of subject benchmark statements suggests a requirement that could be fulfilled by competence frameworks. An academic sector could define a reference point against which any particular institution could define the intended outcomes of their educational courses in a way which permitted comparison with other institutions.

Governmental and administrative bodies may also have their own kinds of requirements from frameworks, to support, for example:

- the mobility of learners and workers;
- analysis of labour market intelligence;
- education and training policy and funding.

The European Qualifications Framework (EQF) is interesting to consider in this context.

The EQF documentation [3] states that it "would establish a common reference point – referring to learning outcomes and levels of competence – simplifying communication between providers and learners in education and training." This clearly makes the connection with competence frameworks.

One may consider possible future requirements as well. It seems possible to imagine a general-purpose system for finding people with particular skills or competence, but, among other challenges to implementing such a system, it would require a common framework acting as a reference point for any parties who wish to participate in such a system.

3 Critique

The examples introduced above each have problems which need to be taken into account in any search for ways forward with practical frameworks.

One of the two principal dimensions of the SFIA framework is the level of responsibility. The SFIA levels are:

1. follow
2. assist
3. apply
4. enable
5. ensure, advise
6. initiate, influence
7. set strategy, inspire, mobilise.

These levels are certainly plausible for many skills, and SFIA maps out which levels are considered as relevant to each particular skill. For each level, four areas of responsibility are distinguished: autonomy; influence; complexity; and business skills. Descriptions of each level of these four areas are grouped together. But how universal are these groupings? There seem to be no specific arguments or justification about why they should be taken as universal. If, for example, many individuals, within a certain skill, display level 2 autonomy but level 4 business skills, the clarity of the level distinctions would be compromised.

Considering this together with the EQF invites further questions. There is a key table in the EQF consultation document, with eight levels on one axis and six areas of application on the other: one for knowledge; one for skills, and four for aspects of "personal and professional competence". As applied to skills, which might be expected to have some correspondence with SFIA, the EQF levels are given as follows.

1. Use basic skills to carry out simple tasks.
2. Use skills and key competences to carry out tasks where action is governed by rules defining routines and strategies.
   Select and apply basic methods, tools and materials.
3. Use a range of field-specific skills to carry out tasks and show personal interpretation through selection and adjustment of methods, tools and materials.
   Evaluate different approaches to tasks.
4. Develop strategic approaches to tasks that arise in work or study by applying specialist knowledge and using expert sources of information.
   Evaluate outcomes in terms of strategic approach used.
5. Develop strategic and creative responses in researching solutions to well defined concrete and abstract problems.
   Demonstrate transfer of theoretical and practical knowledge in creating solutions to problems.
6. Demonstrate mastery of methods and tools in a complex and specialised field and demonstrate innovation in terms of methods used.
   Devise and sustain arguments to solve problems.
7. Create a research based diagnosis to problems by integrating knowledge from new or inter-disciplinary fields and make judgements with incomplete or limited information.
   Develop new skills in response to emerging knowledge and techniques.
8. Research, conceive, design, implement and adapt projects that lead to new knowledge and new procedural solutions.

The obvious question is, do these levels map in any way onto the SFIA levels? Unfortunately there appears to be no clear mapping – for instance it is not the case that two of the EQF levels neatly map onto one of the SFIA levels, with the rest corresponding one-to-one.

Such difficulties suggest a preference for avoiding trying to defineuniversal levels in frameworks that are meant to be of widespread applicability. Instead, a more flexible approach to indicating progression of competence would be to allow the definition of pre-requisite competences for any particular competence definition.

On the other hand there is the relative informality of the subject benchmark statements also mentioned above. Whereas one can see SFIA and the EQF proposing too inflexible a structure in terms of levels, they are attempting to provide schemes which can be referenced by anyone to locate a particular competence description. Subject benchmark statements, on the other hand, do not have sufficient structure to provide such a common reference scheme. In practice, this might mean that a system which attempted to use subject benchmarks as a reference would be too complex and difficult to use in practice.

4 The key issue: common v. specific frameworks

Looking back at the list of requirements, and in view of the critique above, one can discern a tension between tendencies pulling in two opposing directions: towards having a different framework for every specific context, and towards having a common, shared framework of competence.

On the one hand, there are many reasons why people need to develop frameworks which are tailored to represent their specific needs. A particular company will have a specific set of competences which are required, along with generic skills, to perform the activities of the business. To an even greater extent, each individual is likely, insofar as he or she is consciously aware of the matter, to have their own list of what they consider or desire as their own competences. In universities and educational institutions teaching a broad range of subjects, there may be a particular motive to emphasise the particular competences which graduates of that particular institution have, distinguishing them from graduates of other institutions.

On the other hand, there are perhaps even more compelling reasons why competence frameworks need to be shared between different bodies, and developed in common.

- The competences developed in educational institutions need to relate to the competences required in employment or subsequent education.
- If individuals are to "plan for their personal, educational and career development", they need to know in commonly understandable terms what competences may be required, and how and where to acquire them.
- Labour mobility demands that individuals educated or trained in one place should be able to find work in other places. This implies that the competences gained in one context need to be able to be represented meaningfully in other contexts.
- For many professions, either regulatory bodies or professional associations need to know that standards of competence are adhered to.
- Software and systems developed for a shared framework could be much cheaper than for a bespoke framework.

Both extreme positions, corresponding to these two opposing tendencies, appear to be untenable alone. An insistence on a completely common framework would deny the freedom to experiment, and the freedom for views to differ about which competences are necessary for which roles. But a fragmented approach, where every organisation has its own competence framework, would make life very difficult for self-directed lifelong learners with multiple, diverse and complex career paths – corresponding to contemporary expectations in our modern society driven by economic rationality. To fulfil the requirements, there needs to be a judicious blend of common and specific approaches, and this paper continues by considering how this might be done.

5 Strategies for fulfilling the requirements and resolving the central issue

The JISC-funded SPWS project (http://www.elframework.org/projects/spws) grappled with some of these questions about frameworks [4]. We suggested that a suitable "meta-framework" for these frameworks of skills and competence should:

- focus attempts at agreement on those things on which it was likely to be in people's interests to agree;
- allow people to disagree on the rest: specifically on how best to design courses or programmes intended to result in improvements in people's abilities.

The SPWS meta-framework therefore allows for two interrelated kinds of framework:

- common or shared frameworks, relatively loose, amenable to agreement, for generic, shared competency definitions in any particular domain;
- specific, "operationalised" frameworks, designed more tightly to suit the requirements of a particular body.

For common frameworks of shared skill or competency definitions, SPWS recommended a faceted approach, to avoid excessive fragmentation into an unmanageable number of independent definitions.

The idea of representing relationships between these common, shared competence definitions using Topic Maps standards (see http://www.topicmaps.org/) is attractive. "Topic maps are a new ISO standard for describing knowledge structures and associating them with information resources" [5]. Each competence concept corresponds to a Topic Maps subject, while relationships to do with composition and pre-requisite competence can be represented by Topic Maps associations. The use of Topic Maps goes beyond the SPWS suggestions.

Specific frameworks of competence for specific contexts invite greater detail in their definition. For example, when developing a curriculum or syllabus for an educational programme, it is good practice to go beyond a simple listing of the general topics to be covered, towards detailing the educational objectives, the learning outcomes, and the manner by which the developed competence will be assessed. This, in turn, will enable a more principled approach to devising learning materials suitable for that curriculum.

Establishing a clear division between common and specific frameworks will go at least much of the way towards providing the conceptual, intellectual basis on which such frameworks can be more stably built.

There are several ways in which specific frameworks may relate to a common, shared framework. Any competence in a specific framework may be represented as having a relationship with a competence drawn from a common, shared framework. These are extremely important relationships, which allow people to understand that a competence in one specific framework is intended to be essentially the same competence as represented in a different specific framework. Following on the Topic Maps line of thinking, specific competences in specific contexts could be represented as Topic Maps occurrences of the Topics represented in a shared competence framework topic map.

To further reconcile the opposing tendencies, it is suggested that people should

- restrict the use of levels to specific frameworks, not common ones
- promote dialogue between the users of specific frameworks, to work towards the creation and development of common frameworks as described above.

There will be a substantial challenge in working towards the establishment of actual shared, common competence frameworks. Agencies or organisations need to be found who are prepared to take on the role of maintaining the common frameworks in their respective areas. In the UK, the Sector Skills Councils (see http://www.ssda.org.uk/) are one obvious candidate. At a European level, it is possible that an agency such as CEDEFOP (http://www.cedefop.eu.int/) might act in this way. Consensus on an agreed information model for a competence framework is also essential, and it is hoped that the ideas proposed here can help towards this.

Developing coherent specific competence frameworks may, if anything, be even more challenging than setting out common frameworks. The scale of the task could perhaps be compared with "business process redesign" or "enterprise resource management". For instance, an educational institution might aim to associate all its resources, course information and teaching and learning materials with a competence framework suitable for that institution; and then to relate that to a common framework established for that sector.

There are a number of e-portfolio related technologies that could use such frameworks, and conversely could be used as test beds for their implementation. LUSID, as referred to above, is certainly one such; it may be that the Open Source Portfolio (http://www.osportfolio.org/) could be another one. However, there are many such systems that do not have structures corresponding to a framework of skills or competence. For these systems, software developers could be invited to build their software to support or integrate with competence frameworks as suggested.

6 Conclusions and further work

This paper takes up the key point whose investigation was started in the SPWS project: that a clear distinction needs to be made between the structure of frameworks intended for common agreement, and that of frameworks intended for specific application or implementation. Making the distinction clear allows a constructive relationship between common, agreed frameworks and specific frameworks that are tailored to particular educational or business processes, including assessment.

Standards in the area need further development, beyond the current leading work of IEEE in their "Reusable Competency Definitions" (http://ltsc.ieee.org/wg20/). In particular, standards for competence frameworks need to be developed, to add to the standards for individual definitions.

E-learning tools, and particularly e-portfolio tools, need to build in support for dealing with competence definitions and frameworks. Inevitably this will be difficult before standards are agreed, but a start needs to be made somewhere, and far-sighted software developers are good candidates for helping to get the process moving. Without effective and agreed competence frameworks, the usefulness of putting together evidence for competence within portfolios will be limited to the context in which the evidence was gathered. LUSID, as introduced above, provides a useful initial model of application in the e-portfolio domain.

Enterprise ontologies, or any conceptual basis for enterprise information management, need to include the idea of competence frameworks, and enterprises that use such frameworks need to adopt the dual approach proposed here, so that they have the freedom to tailor their frameworks to their own needs, while at the same time retaining allowing reference to common definitions, thus, for example, making the skills and qualities sought in the recruitment processes open to use by e-portfolio and other tools.

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Enhancing the Social Network Dimension of Lifelong Competence Development and Management Systems: A Proposal of Methods and Tools

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Abstract:

Competence Development and Management Systems (CDMS) belong to the category of knowledge management systems, which are structured online repositories of knowledge assets that a community of users accesses and maintains on a continuous basis for learning and knowledge sharing purposes. This concept paper addresses the challenge of enhancing the social dimension of CDMS with social network-based concepts and tools. Our premise is that knowing about and having access to the social network can help with decision-making and inform targeted efforts to promote knowledge exchange among learners. A series of tools will be presented, such as social network visualization, simulations, stimulus agents and network management policies with the aim of increasing the visibility and value of social resources within CDMS and opening up knowledge sharing opportunities among a community of CDMS users.

Keywords: Knowledge and Competence Management, Social Network Analysis, Network Visualization, Simulation, Stimulus Agents

1. Introduction

Competence development and management systems (CDMS) are computer-based, typically web-based systems centered on the organization and distribution of lifelong competence development programs. Although these systems have, as their objective, the provision of seamless and ubiquitous access to a variety of learning opportunities, they also rely on an active, participatory community of users.

This community consists of diverse learners who want to upgrade their knowledge, skills and proficiency in a discipline or profession, and may also include instructors who need assistance in designing learning activities, organizations and learning institutions in the process of implementing a competence development course, content and course providers who want to introduce new learning programs, and practitioners and other stakeholders who are interested in engaging in discourse within a field. The heterogeneity within such a system opens up opportunities for members to draw upon the expertise of others and to contribute to the collective body of knowledge.

Over the past years, the community approach [1], and in particular, knowledge communities and communities of practice [2], have emerged as an important paradigm for supporting the transfer of both tacit and explicit knowledge as well as the creation of knowledge within distributed groups [3][4].

According to Wenger et al, the success of a community depends on its social space, the characteristics of its members and the characteristics of the community as a whole [5]. Additionally, individual success or failure in a learning community has been associated to the extent to which learners perceive themselves as members and participants of that community [6]. Those who are not socially embedded into the community are less likely to flourish in it.

Part of the challenge within the design of successful communities is the difficulty in engaging community members in knowledge exchange and creation, establishing a sustainable level of engagement, and empowering these communities to become self-organizing, self-directed entities [7][8].

This concept paper addresses the following two questions: (1) how to better connect CDMS users to one another to create a sense of community for knowledge sharing purposes, and (2) how to engage ongoing active participation of individuals toward increased self-direction and self-organization.

We begin with a description of the some of the questions learners might have related to their search for competence development opportunities. We then propose a social network-based approach to facilitate connections among users and hence, open up opportunities for knowledge exchange among them. This will be followed by an exploration of how current CDMS design may be extended with interactive social network visualizations, simulations, stimulus agents and management policies toward the creation of a self-organizing, self-directed community of CDMS users.

2. The social nature of knowledge work

Learners in search of competence development opportunities have a variety of strategies towards accomplishing their objectives. They may do a general or specific search to discover various possibilities; then focus their attention on the more relevant and attractive option. To this effect, online repositories can help structure and make more efficient a learner's knowledge search.

However, as very often happens in practice, knowledge seeking also takes place socially, with people drawing from the knowledge, experiences know-how of others [9][10]. When faced with a knowledge need, learners often turn to who they know who might be able to provide the relevant information, as reflected in the following questions:

- *Who could I access who actually uses/applies the targeted competences on a regular basis?*
- *Who could I access who has gone recently through an experience similar to the one I am going to embark on?*
- *Who could I access who can provide me advice on how to best proceed in developing the targeted competencies?*
- *Who could I access who can provide me with the targeted competences in a "real-time" mode (i.e. learning in progress)?*
- *Who could I access who can advise me on which document/site/programme is the most efficient/most pleasant way of developing the targeted competencies?*
- *Who could I access who can provide me direct or indirect access to the people listed above?*
- *Which type of access to all these people can I actually get?*

In the next section, we borrow from knowledge management literature and business practice to emphasize the importance of the sets of relationships that people rely on to accomplish their knowledge work. We then propose a series of guidelines for the integration of a social networks perspective into the design of CDMS.

3. The evolution of knowledge and competence management towards more socially oriented systems

In a recent review of knowledge management research and practices, Hong and Stahle [11] noted the emergence of a new generation of knowledge management systems focused on the dynamic *self-organization* of knowledge and the *creation of new knowledge* and competences. This approach builds on previous generation systems which first emphasized locating, capturing and delivering knowledge, followed by the integration of concepts such as tacit knowledge, social learning and communities of practice toward knowledge sharing and transfer.

This shift toward a more socially-oriented perspective is mirrored within competence management literature. Recently, competence development is mainly seen not as the management of existing competences but as an *innovative learning process*, which requires the management of competences as they emerge from ongoing practices and activities.

We also borrow from current knowledge management practices within the business realm to illustrate the importance of supporting social networks. More and more, companies are focusing on the value of relationships and social connections. The traditional aspect of the managerial role has taken a new dimension, as reflected in the so-called "post bureaucratic" or "network" organization [12]. Mapping the network of "who knows what" and "who knows who" in a group gives members insights and opportunities to tap into the expertise of their colleagues [13].

As such, traditional companies are now observed to be experimenting with network design. General Electric is turning into the ultimate network organization: the *boundaryless* organization composed of a seamless network of relationships. Within such a company, members of the group are dispersed across different geographic sites and hierarchical levels and bring together different kinds of expertise.

Within such organizational paradigms, success depends more and more on relationship skills: how well one builds good relationships with peers, superiors, subordinates, groups, teams, customers, suppliers and investors. Other companies such as Ericsson, IBM and others are practicing similar approaches [14] [15].

Based on the direction of knowledge management literature and business practice, we would like to apply a social networks dimension into the area of competence development. Our hypothesis is that knowing about and having access to the social network can help with decision-making and inform targeted efforts to promote knowledge exchange among learners.

4. Integrating social networks into the design of CDMS: Objectives and Guidelines

Networks, generally defined as specific types of relations linking defined sets of people, objects, or events [16], provide access to learning opportunities. Those with connections have a greater capacity to leverage resources, ideas and information from the community [17]. Furthermore those with connections outside their immediate peer group, i.e. with individuals in different social positions, power or expertise, are able to broker these relationships towards securing access to further opportunities, external information, and knowledge gathered by others in the community [18][19].

Our approach is that by focusing on the social network dynamics (SND) within CDMS, user experiences may be designed that have a significant impact on:

1. The *number* of connections between network members;
2. The *value* derived from user experiences in the network in terms of helping users meet their objectives efficiently;
3. The *attitude* and *behavior* of users, with respect to pro-active knowledge exchange and collaborative involvement.

We anticipate that making visible, explicit and meaningful to users the value of the network may affect user motivation and levels of engagement. Such a system would provide not only information and resources related to competence development, but also map the network of people who produced or use the information.

The design of such systems should include the following principles: greater efficiency, more usable information, increased cohesiveness, more productive user exchanges, and higher user involvement.

4.1 Greater Efficiency in the Navigation Process

As online curricula multiply, users are faced with many options and often find it difficult to gain an overview of what is relevant and what is not. The most common navigational tool is a search engine intended to help users identify quickly the most relevant information. Depending on how the information is organized and the sophistication of the search query, the process may be quick or it may involve a tedious sifting of valuable from less valuable information. Additionally, representations of relationship networks such as those among people (P2P) and between people and competence development programs (P2CDP) can provide enhanced navigation within the system, by having learners use other learners as pointers toward resources and learning opportunities. To date, a network or community is represented mainly in the form of a directory. More innovative and dynamic approaches may be used to link knowledge and knowledge resources to the people who possess and use them.

4.2 More usable information

Knowledge work that focuses only on the retrieval of information from repositories will largely ignore a large part of knowledge that is not present in documents, i.e. *experiences, social knowledge, and know-how*. Within a network community, the experience of others serves as a filter for identifying the most appropriate and "tested" learning paths [20][21]. CDMS users may identify other users with similar learning objectives or users who have already achieved their targets, and seek advice and recommendations that are based on actual practice.

4.3 Increase the cohesiveness of group relationships

Social networking is a natural means for individuals to get to know others in their field and to seek out knowledge. Fostering networking processes and maintaining and strengthening ties within groups help reinforce the glue with which a community is bounded together [22]. Communities marked by higher levels of cohesiveness also exhibit higher levels of trust [23]. Research has shown that trust is a key factor to the development and maintenance of groups and communities [24][25]. Companies themselves recognize the importance of the "water-cooler" for facilitating interpersonal relationship building, the formation of both strong and weak ties, the development of trust, and the transfer of knowledge [26].

4.4 Stimulate productive exchange

Cooperation is powerful if it leads to the leveraging of resources, ideas and information towards fulfilling ones personal and professional goals. Peer interactions can lead to emergent knowledge [27], stimulate reflection, improve self-esteem, commitment to work, a sense of belonging and higher levels of participation [28]. Collaborative activities may also bring in a higher-level discourse which includes the exchange of ideas, explanations, justifications, speculations, inferences, hypotheses and conclusions that lead to more productive exchange and new learning [29]. As Woolcock notes, "*the latest equipment and most innovative ideas in the hands or mind of the brightest, fittest person, however, will amount to little unless that person also has access to others to inform, correct, improve and disseminate his or her work*" [30].

4.5 Higher user involvement

Through social and collaborative experiences, individual learning may be extended to what one might accomplish alone [31]. Constructivist principles positions the learner in an active role, and responsible for not only in ones own learning but influencing the learning of others as well [32]. The challenge to community design remains with how to potentially transforming passive learners who receive of pre-packaged learning courses and activities into active contributors to the knowledge space.

5. TenCompetence- Building the European Network for Lifelong Competence Development

TenCompetence is a large, multi-year, research project-in-progress sponsored in part by the European Commission. The project aims to establish the most appropriate on-line and open-source technical and organizational infrastructure to support individuals, groups and organisations within Europe in lifelong competence development.

The project provides an ideal context for research and experimentation related to the enhancement of the social dimension within CDMS. As mentioned, the social dimension has been recognized as an essential component of knowledge management, with the understanding that in the absence of continued user participation, engagement and ownership, such systems will eventually become obsolete [9][10].

To avoid this, we are proposing the introduction of a number of features to enhance current CDMS. Such features range from *social network analysis and visualization tools* that facilitate communication and exchange, to more innovative approaches such as *advanced simulations* to scaffold networking and knowledge exchange behavior, and to the use of *stimulus agents* acting on user models to propose networking choices and to highlight cooperative opportunities. Additionally, *policies of self-organization* (terms of use, standards and quality, reward system, membership/ role) will be tested to guide how users learn, share and create knowledge and support each other.

Figure 1 shows the connections between the proposed methods/tools and related design principles.

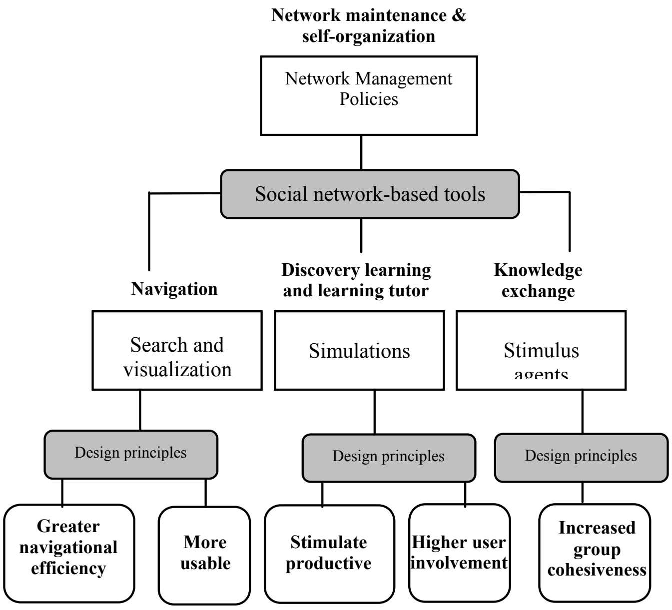

Figure 1. Social network-based models and tools and design principles

6. Proposed methods and tools

6.1 High-level visualization of social networks and competence development programs

Most existing search engines for information work off a query to present users with a list of documents. However, our objective is to test the impact of information delivered in a more interactive and dynamic form such that it reflects the structure of underlying social networks. Additionally, searching for individuals is equally important as these represent the source of 'tacit' knowledge oftentimes missing from a list of documents.

To this effect, interactive visualizations of the people and processes (who is interacting with who and on what) will assist in making the CDMS space more tangible and easier to navigate [33]. These visualizations will present knowledge as a web of connections which users may explore and discover. They will also include a very synthetic and rich view of useful and usable information, be adapted to user profiles and current learning objectives, and open up opportunities for collaboration and community building. Technologies similar to Kartoo [34], a metasearch engine with visual displays and other open source software (Touchgraph [35], Inflow [36], etc) may serve as examplars.

We anticipate the visualization of networks to enable greater efficiency in navigation (see section 4.1), to include not only navigation toward relevant knowledge resources, but also towards knowledge bearers (see section 4.2).

6.2 Games for promoting discovery, socialization and collaborative behavior

Simulations, in the form of games, provide a learning-by-doing approach [37] that may guide users toward discovering the social network structure and networking opportunities within the CDMS. Serious games have been in the market for a number of years, and have played a significant role in training activities in certain sectors, notably those in defense and aviation. Driven by falling technology costs, rising technological capabilities and changing attitudes of users, serious games are quickly moving into other sectors as serious tools with business relevance [38].

Within the educational contexts, games have been successfully and extensively used to develop the competencies of managers, engineers and decision-makers in top business schools (such as MIT, Stanford, etc.) in managing change and innovation in different types of organizational contexts [37][39].

A concrete example of a learning experience which can be classified as a *SmallWorld Simulation* is the 'EIS Simulation' [40][41] which has been widely adopted over the last few years to substitute or complement traditional ways of teaching change management competencies to engineering and management students, as well as to experienced executives.

The objectives (see Figure 2) of such simulations are to:

- Gradually increase the level of **familiarity** of each user with a specific space or feature of the overall system:
- Increase the **value perceived** by each user from using the system by locating and

suggesting the 'exploration' of valuable spaces, knowledge assets and members: and

- Gradually increase the level of **participation/involvement** of each user.

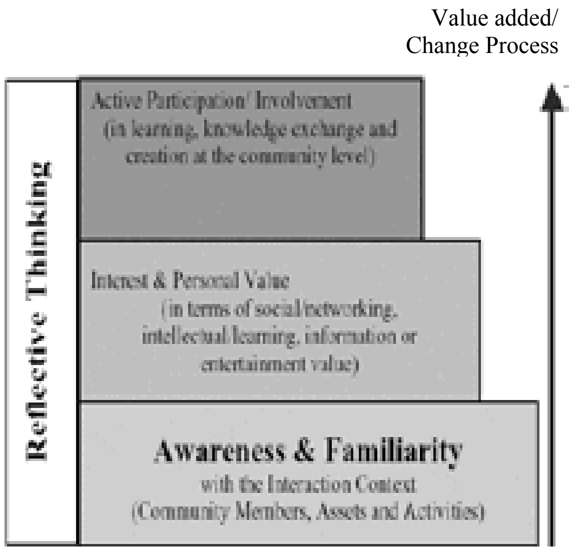

Figure 2. Change Process within Simulated Games

Based on the EIS simulation, we propose developing a similar simulation-based learning experience for CDMS users. This simulation will consist of a network of professionals within a field, with simulated characters, each with a competence profile as well as connections to competence development opportunities. Users playing the simulation will be given a mission that will launch them into an exploration and experimentation with social network space and its features.

We anticipate the impact of the simulations to be three-fold:

- Users will become familiar and adapt to the virtual environment. They will do so by gaining an understanding of social networks, developing navigation skills, and discovering system spaces and their communicative and collaborative features.
- Users will undergo socialization on a continual basis as the simulation assists them in forming connections among people.
- The gradual adoption of 'desired' behavior, i.e. transforming users from lurkers to active contributors.

These games will be designed with the intent of stimulating more productive exchange (see section 4.4) and higher user involvement (see section 4.5) by scaffolding users' social and knowledge seeking experiences within the network.

6.3 Stimulus agents based on Social Network Analysis tools

According to Cohen and Prusak, "*knowledge flows along existing pathways in organizations. If we want to understand how to improve the flow of knowledge, we need to understand those pathways*" [42].

Social network analysis (SNA) is a method for collecting, analyzing and presenting data about patterns of relationships among people and knowledge flows within a network [43][44]. As a knowledge management practice [45], SNA has been used to study knowledge flows [46], the emergence of groups and the quality of their social relationships [47], as well as collaboration, innovation and knowledge diffusion [48][49].

Data from SNA may be leveraged to accelerate the flow of knowledge and information across functional and organizational boundaries; to identify the thought leaders, key information brokers and bottlenecks; and to identify opportunities for increasing impact by increasing flow.

Stimulus agents will act on SNA data as well on information from user profiles to generate interventions to stimulate the participation of users [50][51]. Agent interventions may include suggesting connections among users, setting up groups, closing the gaps in people's knowledge of other members' expertise and experience, and strengthening the cohesiveness within existing teams [52].

These agents will serve as knowledge exchange facilitators, working towards increasing the cohesiveness of group relationships (see section 4.3).

6.4 Policies for managing the network

The practical measures discussed thus far all support users in deriving more value from the network by fine-tuning their attitudes and behavior. But what if users do not comply? By serving one's own personal goals, the network as a whole may suffer.

Crucially, all users are expected to contribute without necessarily receiving an immediate payback, although in the long run, they should expect to be compensated. This expectation is only born out if it is rational for an individual user to contribute without immediate payback. The user's decision will therefore be influenced by the following considerations:

- What is the expected value of the payback?
- What is the time-lag between the investment and the payback?
- What is the expectation to be paid back at all?

The ability to gauge these expectations depends on the *transparency* of the network. As an investor of time and effort, a user should be able to quickly estimate the *quality of the network*, the *speed with which queries are resolved*, and *the likelihood of being helped at all by peers*. Visualization tools, games, and user agents all help users to better make these assessments.

However, it is the *values* of all three that ultimately determine someone's decision. These depend on the collective behaviors of all users [53]. Powerful drivers to stimulating high quality contributions include community norms and gains in reputation [54][55].

Accordingly, a variety of management policies will be explored [29]:

- Adopting some means of rewarding (or punishing) users whose behavior is conducive (or detrimental) to network survival
- Forbiding anonymity to reveal free-loaders, i.e. those who take without ever contributing
- Adopting some, not necessarily monetary currency to measure and compare users' contributions with respect to their value for the network

These and similar policies, the details of which depend on the network's precise configuration, are the ultimate drivers behind a network's capacity for self-organization.

7. Conclusions

A community thrives not only on its resources, but also on the relationships among its members. However, the emergence of a community of knowledge workers within which members actively exchange and create knowledge remains a major challenge within online competence development and management systems. We address this challenge through a social-networks based approach, focusing on the connections between people and supporting knowledge exchange activities once these connections are set up.

At the current stage of the TenCompetence project, no empirical studies exist for the set of tools illustrated. Next steps will include developing a complete framework to describe the effects and interactions of these tools toward the adoption of pro-active networking and knowledge sharing behavior. We envision that such a framework will be modeled as a *change process* in which users become increasingly more invested, self-organized and self-directed in their knowledge-related activities.

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