

THE UNIVERSITY OF HULL

Ontology-Based Personalisation of E-Learning Resources for Disabled
Students

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by

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Abstract

Students with disabilities are often expected to use e-learning systems to access learning materials but most systems do not provide appropriate adaptation or personalisation to meet their needs.

The difficulties related to inadaptability of current learning environments can now be resolved using semantic web technologies such as web ontologies which have been successfully used to drive e-learning personalisation. Nevertheless, e-learning personalisation for students with disabilities has mainly targeted those with single disabilities such as dyslexia or visual impairment, often neglecting those with multiple disabilities due to the difficulty of designing for a combination of disabilities.

This thesis argues that it is possible to personalise learning materials for learners with disabilities, including those with multiple disabilities. This is achieved by developing a model that allows the learning environment to present the student with learning materials in suitable formats while considering their disability and learning needs through an ontology-driven and disability-aware personalised e-learning system model (ONTODAPS). A disability ontology known as the Abilities and Disabilities Ontology for Online LEarning and Services (ADOOLES) is developed and used to drive this model. To test the above hypothesis, some case studies are employed to show how the model functions for various individuals with and without disabilities and then the implemented visual interface is experimentally evaluated by eighteen students with disabilities and heuristically by ten lecturers. The results are collected and statistically analysed.

The results obtained confirm the above hypothesis and suggest that ONTODAPS can be effectively employed to personalise learning and to manage learning resources. The student participants found that ONTODAPS could aid their learning experience and all

agreed that they would like to use this functionality in an existing learning environment. The results also suggest that ONTODAPS provides a platform where students with disabilities can have equivalent learning experience with their peers without disabilities. For the results to be generalised, this study could be extended through further experiments with more diverse groups of students with disabilities and across multiple educational institutions.

Dedication

To my parents: Manasses N. Nganji (of blessed memory) and Rebecca M. Nganji

who lived selflessly in order to help each of us achieve our dreams.

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Author's Declaration and Publications

Some of this research has been presented at international conferences and parts of this thesis have thus been published, appearing in some of these publications:

Journal Articles

1. Nganji, J.T., and Brayshaw, M. (2015). Facilitating Learning Resource Retrieval for Students with Disabilities through an Ontology-Driven and Disability-Aware Virtual Learning Environment. *International Journal of Information Retrieval Research (IJIRR)*, vol 5, Issue 3, pp. 75-98.
2. Nganji, J.T., Brayshaw, M. and Tompsett, B. (2013). Ontology-Driven Disability-Aware E-Learning Personalisation with ONTODAPS. *Campus Wide Information Systems*, vol.30, Iss: 1, pp. 17-34.
3. Nganji, J.T. (2012). Designing Disability-Aware E-Learning Systems: Disabled Students' Recommendations. *International Journal of Advanced Science and Technology*, vol.48, pp. 61-70.
4. Nganji, J.T. and Nggada, S.H. (2011). Disability-Aware Software Engineering for Improved System Accessibility and Usability. *International Journal of Software Engineering and Its Applications (IJSEIA)*, Vol. 5, No.3, pp.47-62, July 2011.
5. Nganji, J.T., Brayshaw, M. and Tompsett, B. (2011). Ontology-Based E-Learning Personalisation for Disabled Students in Higher Education. *Innovation in Teaching and Learning in Information and Computer Sciences (ITALICS)*, Vol. 10, Issue 1, pp.1-11.

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1. Nganji, J.T., and Brayshaw, M. (2015). Personalizing Learning Materials for Students with Multiple Disabilities in Virtual Learning Environments. *Science and Information Conference (SAI) 2015*, July 28-30, London, United Kingdom, pp. 69-76.
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3. Brayshaw, M., Gordon, N., Nganji, J., Wen, L., and Butterfield, A. (2014). Investigating Heuristic Evaluation as a Methodology for Evaluating Pedagogical Software: an Analysis Employing Three Case Studies. 16th International Conference on Human-Computer Interaction-HCII2014, 17-22 June, Crete, Greece, *Lecture Notes in Computer Science*, Vol. 8523, pp.25-35.
4. Nganji, J. T., Brayshaw, M, and Tompsett, B. C. (2013). Describing and Assessing Image Descriptions for Visually Impaired Web Users with IDAT, *In 3rd International Conference on Intelligent Human Computer Interaction*, Springer-Verlag, Lecture Notes in Computer Science, August 2011, reprinted in *Advances in Intelligent Systems and Computing*, Volume 179, Springer Verlag, 2013, pp 27-37, ISSN: 2194-5357 (Print) 2194-5365 (Online).
5. Nganji, J.T., and Brayshaw, M. (2011). Towards an Ontology-Based Community of Agents for Personalisation of Services for Disabled Students. In: Blashki, K. (Ed.). *Proceedings of the IADIS International Conference Interfaces and Human Computer Interaction (IHCI 2011)*, 24-26 July 2011, Rome, Italy, pp. 193-200.

Book Chapters

1. Nganji, J. T., & Brayshaw, M. (2013). Designing Personalised Learning Resources for Disabled Students Using an Ontology-Driven Community of Agents. In P. Isaias, & M. Baptista Nunes (Eds.), *Information Systems Research and Exploring Social Artifacts: Approaches and Methodologies* (pp. 81-102). Hershey, PA: Information Science Reference. doi:10.4018/978-1-4666-2491-7.ch00

Other Publications

1. Nganji, J. T., & Nggada, S. H. (2014). Adoption of Blended Learning Technologies in Selected Secondary Schools in Cameroon and Nigeria: Challenges in Disability Inclusion. In N. Ololube (Ed.), *Advancing Technology and Educational Development through Blended Learning in Emerging Economies* (pp. 159-173). Hershey, PA: Information Science Reference. doi:10.4018/978-1-4666-4574-5.ch009
2. Nganji, J.T. (2015). The Portable Document Format (PDF) Accessibility Practice of Four Journal Publishers. *Library and Information Science Research*, Vol. 37, Issue 3, pp. 254-262.

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Abbreviations

AAC	Augmentative and Alternative Communication
ACCLIP	Accessibility for LIP
ADL	Advanced Distributed Learning
AICC	Aviation Industry Computer-Based Training Committee
ADOLENA	Abilities and Disabilities OntoLogy for ENhancing Accessibility
ADOOLES	Abilities and Disabilities Ontology for Online LEarning and Services
AHAM	Adaptive Hypermedia Application Model
ALD	Assistive Listening Device
ANOVA	Analysis of Variance
APLE	Adaptable Personal Learning Environment
ASK-IT	Ambient Intelligence System of Agents for Knowledge-based and Integrated Services for Mobility Impaired users
CMI	Computer Managed Instruction
CSD	Centre for Students with Disabilities
DAML	DARPA Agent Markup Language
DCMI	Dublin Core Metadata Initiative
DDA	Disability Discrimination Act
DfES	Department for Education and Skills
DIUS	Department for Innovation, Universities and Skills
ELT	Experiential Learning Theory
EORM	Enhanced Object-Relationship Model
EU	European Union

EU4ALL	European Unified Approach for Accessible Lifelong Learning
FN	False Negative
FOAF	Friend of A Friend
FOHM	Fundamental Open Hypermedia Model
GPS	Global Positioning system
GUI	Graphical User Interface
HESA	Higher Education Statistics Agency
HTML	HyperText Mark-up Language
ICF	International Classification of Functioning
ICT	Information and Communication Technology
IDA	International Dyslexia Association
IDAT	Image Description Assessment Tool
IEEE	Institute of Electrical and Electronic Engineers
LIP	Learner Information Package
LMS	Learning Management System
LOM	Learning Object Model
MOOC	Massive Open Online Course
OIL	Ontology Inference Layer
ONTODAPS	Ontology-Driven Disability-Aware Personalised E-Learning System
OOHDM	Object Oriented Hypermedia Design Model
OSK	On-screen Keyboard
OWL	Web Ontology Language
PAL	Profile for Adaptable Learning
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema

SASS	Student Academic Success Service
SCORM	Sharable Content Object Reference Model
SENDA	Special Educational Needs and Disability Act
SMORE	Semantic Markup, Ontology and RDF Editor
SPARQL	SPARQL Protocol and RDF Query Language
SPSS	Statistical Package for Social Sciences
TN	True Negative
TP	True Positive
TURTLE	Terse RDF Triple Language
UK	United Kingdom
UML	Unified Modelling Language
URI	Uniform Resource Identifier
VARCK	Visual, Aural, Read/Write, Kinaesthetic
VLE	Virtual Learning Environment
WAI	Web Accessibility Initiative
WCAG	Web Content Accessibility Guidelines
W3C	World Wide Web Consortium
WHO	World Health Organisation
WWW	World Wide Web
XML	eXtensible Markup Language

Although the development towards web-based higher education is a great opportunity for these students and can imply a significant gain in inclusion, the reality is often gloomy with web-based higher education failing to transpose the basic accessibility notions from the physical to the digital environment. As a result, the current development towards web-based higher education includes the threat of increased exclusion.

Jan Steyaert

“Web-Based Higher Education: The Inclusion/Exclusion Paradox”

(Steyaert, 2005)

Chapter 1: Introduction

1.1 Scope and Context

Learning is a process of discovery, which involves the use of the senses to take in and process information usually through cognition. Traditionally, teaching and learning in a higher education context involved the lecturer standing in front of students and delivering lectures, often demonstrating concepts on a board (Orlander, 2007, Ohare, 1993, Wyatt, 1977). For some students with disabilities, the senses are affected, which negatively impacts on learning when appropriate interventions which may include assistive technology are not employed. Hence, visual illustrations on a board in traditional teaching would exclude a student with visual impairment. The presence of disability for some students means that they are potentially disadvantaged in comparison to those without disabilities. Thus, it has been reported that students with disabilities have lower chances of obtaining a good degree than their peers without disabilities (DIUS, 2009).

Fortunately, the introduction of technology into learning has brought about many improvements, which have enhanced teaching and learning. Thus, educational institutions worldwide are increasingly employing virtual learning environments to create and deliver courses (Lin et al., 2014, Bharuthram and Kies, 2013, Bell and Federman, 2013, Fichten et al., 2009a). It is now possible to produce learning materials that are tailored to the needs of individual students, with the ability for these students to access the materials anywhere and at any time provided they are connected to a network, have the technology required for access and the materials are of the correct format if they have a disability. For students with disabilities, e-learning is advantageous in that learning materials can be presented to them in adapted forms that are delivered according to their special needs and preferences (Power et al., 2010).

Since the use of technology enables exposure to vast arrays of information, higher education institutions need to ensure that students with disabilities have the same access as students without disabilities (Wall and Sarver, 2003).

Nevertheless, the significant use of technology to deliver teaching and enhance learning has also brought about some challenges in the domain of special needs due to the difficulties some students with disabilities face when interacting with technology that is not designed with their needs in mind, thus leading to accessibility barriers (Seale, 2009, Iglesias et al., 2014). With the increasing availability of information online, there is the problem of how to locate the correct learning materials amongst the numerous materials in learning environments (Salehi and Kamalabadi, 2013). Also, not all users may be able to access the information due to disability especially when the delivery format is not appropriate (Power et al., 2010) and hence the need to increase access to online learning materials for such people by presenting material to them based on their preferences, special needs and learning goals through personalisation. Debevc et al. (2010) suggest that "the difficulties and functional barriers of people with special needs mean that they require an adapted environment for education, work and communication, which can be of a technical or interpersonal nature". However, most learning environments do not provide appropriate adaptation (Peter et al., 2010, Tompsett, 2008, Devedzic, 2004) to meet the needs of students and designing for cases of multiple disabilities is difficult to achieve (Petrie et al., 2006). The inadaptability of learning environments seems to arise from the fact that such systems were designed inflexibly (Pahl, 2003). As discussed in Chapter 3, often, designers and developers of such systems tend to follow traditional systems development methods, which may require consulting potential users but does not generally consider consulting or including the needs of users with disabilities (Nganji and Nggada, 2011). It is thus important to consider the needs of people with disabilities throughout the system development

process as discussed in Chapter 3, incorporating accessibility from the start (Laabidi et al., 2014).

As discussed in Chapter 2 of this thesis, although there are numerous learning environments within educational institutions and those resulting from research, which seek to address the needs of students with disabilities, many have the following shortcomings:

- Inadequate adaptation to meet the needs of learners (Peter et al., 2010, Tompsett, 2008, Devedzic, 2004).
- Most are designed without consideration of the needs of students with disabilities, given the difficulties of designing for such disabilities (Fichten et al., 2009a).
- Those built for people with disabilities often focus on specific user groups (Sampson and Zervas, 2011) possibly because it is difficult to design for multiple disabilities (Petrie et al., 2006).
- Inaccessibility of e-learning materials and the e-learning software (Fichten et al., 2009a).
- They do not usually have inbuilt assistive technology to meet the needs of learners with disabilities (Nganji et al., 2013b).

This research seeks to address these challenges by proposing an ontology-driven disability-aware model for personalising learning materials and then developing a disability-aware learning environment as proof of concept. This system will contain many configurations for the different disability types of the learners thus matching

content presentation to the needs of the learner (Nevile and Treviranus, 2006) as will be presented in Chapter 5.

1.2 Motivations

Generally, in a university setting, there is a student support service (Datta and Palmer, 2015), which caters for the learning needs of the student by providing learning support. This could be done through mentoring, note taking and other forms of personalised support. For some students with disabilities, it could be through the provision of individualised assistive technology, which meets specific needs. This is often done after experts at the student support service have assessed the needs of the learner. Adaptation of the physical environment also enables those with mobility difficulties to access lecture halls with less difficulties.

Whilst universities are good at adapting the physical environment to meet the needs of students with disabilities and also with providing individualised support, universities seem to be failing in implementing the same principle in the digital environment (Steyaert, 2005). The challenge of implementing these principles in the digital environment is resulting in a "disability divide" (Hollier, 2007) which can be overcome by breaking accessibility barriers.

Virtual learning environments (VLEs) are prevalent in higher education (Corrall and Keates, 2011). These VLEs - such as Blackboard (Bradford et al., 2006), Moodle (Lin, 2011), Sakai (Yang and Allan, 2007b), Canvas (Canvas, 2014) and Desire2Learn (D2L, 2014) - are used to deliver courses to students. Existing learning environments have accessibility difficulties, which inhibit students with disabilities from gaining full access to learning materials (Iglesias et al., 2014). Consequently, students with disabilities have numerous difficulties accessing e-learning programs (Gil-Rodriguez et al., 2006). Such barriers often result from content authors not producing and posting accessible content

while the authoring tool is not also designed accessibly (Fichten et al., 2009b). This necessitates the search for better solutions to enhance learning for these students. As already discussed in Section 1.1, current learning environments also suffer from the problem of not offering adequate adaptation for users (Peter et al., 2010, Tompsett, 2008) and the problem of matching content to specific users (Costello, 2012). A solution to the difficulties of existing e-learning systems could be to personalise the learning environment to meet the needs of the learner (Power and Paige, 2009). Nevertheless, personalising information to meet special needs also raises the challenge of how to design for multiple disabilities (Petrie et al., 2006) which is seriously lacking in current learning environments in addition to not being able to offer adequate adaptation.

In light of the above challenges to current learning environments, the motivation for this study is to address some of the difficulties and challenges of providing personalised and adaptable learning for students with disabilities through theoretical modelling and implementation of an ontology-driven and disability-aware approach to personalised learning, which takes, into account, the possibility of multiple disabilities within an individual.

1.3 Research Hypothesis, Aim and Objectives

The introduction showed that there are problems with presenting learning to students with disabilities using technology in learning environments. The proposed solution was to personalise content in order to meet specific needs. The problem of matching users to specific content was considered by Costello (2012). However, for students with disabilities to be able to access the correct information, the format of the learning material must be appropriate for them (Power et al., 2010), something that is usually overlooked in current learning environments.

Although it is difficult to design for cases of multiple disabilities, other technology-based research have shown that this is not impossible as researchers have been able to use technology to facilitate learning for people with severe cases of multiple disabilities (Lancioni et al., 2014a). By adapting a standard mouse and enabling an on-screen keyboard (OSK), Shih (2014) was able to increase the computer typing efficiency in participants with multiple disabilities and cerebral palsy. It has also been shown that those with severe forms of multiple disabilities can rely on technology, in order to enable them achieve specific goals if the right technology is used (Lancioni et al., 2014b). However, from critically examining literature on the e-learning domain as discussed in Chapter 2, it was found that existing research on personalising learning for students with disabilities such as those by Tzouveli et al. (2008b) and Schmidt & Schneider (2007) using the AGENT-DYSL approach have mainly focused on pupils with dyslexia, while Ko et al. (2011) only focused on students with learning disabilities with a reading problem. Although recently Laabidi et al. (2014) adapted Moodle and incorporated the ability for learners to choose their disability type and have the learning environment adapt to their needs by presenting content in a suitable format, their research does not deal with personalising for those with multiple disabilities. Therefore, there is very limited research into personalising learning for students with disabilities considering the whole range of disabilities that affect learning, particularly the case of students with multiple disabilities.

Thus, the hypothesis underlying this research is as follows:

Learning materials can be personalised for learners with disabilities, including those with multiple disabilities by developing a model that allows the learning environment to present learners with materials in suitable formats while considering their learning needs.

Thus, an ontology-driven and disability-aware personalised e-learning system, which adjusts to the needs of the learner, including those with multiple disabilities, will increase access to learning materials for students with disabilities.

To test the above hypothesis, the following aim has been set:

The aim of this research is to show how learning materials can be adapted to the special needs of a learner by developing an approach, using the above model that allows for the personalisation of learning materials through considering the disability type and learning goals of the learner.

In order to achieve the research aim, the following research objectives have been set:

- Provide a critical review of literature in the field of learning, disability and personalised e-learning particularly relating to students with disabilities.
- Design a model for personalising learning materials for students with disabilities based on filtration technique.
- Demonstrate through case studies how the e-learning model provides personalisation for single and multiple cases of disabilities and for a student without disability.
- Implement a prototype of the proposed model.
- Evaluate the approach using various experiments with lecturers (heuristic evaluation) and students (experimental evaluation).

1.4 Research questions

The research objectives lead to the following questions:

How can we improve access to online learning materials for students with disabilities?

Students with disabilities face difficulties in accessing digital systems. In order for us to answer this question, literature will be reviewed.

What methodology can be employed to develop accessible and usable e-learning systems?

From examining literature, it can be seen that one of the reasons why learning environments don't meet the needs of some students with disability is because they are inaccessible (Fichten et al., 2009b). A reason for the software being inaccessible is that they are designed using traditional software approaches without considering the needs of the learner (Nganji and Nggada, 2011) and accessibility is not incorporated from the start of the development (Laabidi et al., 2014). Chapter 3 of this thesis reviews some common approaches to designing learning systems for people with disability.

How does the model provide personalisation of e-learning materials for students with disabilities?

A serious deficiency of existing e-learning environments is the conspicuous absence of a mechanism to respond to the needs of learners with disabilities. The ONTODAPS architecture and model will be presented in Chapter 4 and specific case studies will be used in Chapter 5 to demonstrate how this works for various individuals, including those with multiple disabilities.

1.5 Methodology and Methods

In order to identify the gap in the field of personalised e-learning relating to students with disabilities, this research will begin with a critical review of literature with specific focus on personalisation in the domain of e-learning.

With the known difficulties of students with disabilities not being able to access information well due to inaccessibility of e-learning systems and the glaring absence of personalisation for those with multiple disabilities, this research will contribute towards filling this gap. This will be done through the development of an ontology-driven and disability-aware theoretical model.

This approach will be evaluated using case studies in Chapter 5 and also experimentally through an empirical approach including a suite of test beds in various experiments to measure the performance of the model regarding the personalisation offered as well as through heuristic evaluation for usability testing as presented in Chapter 6. Those involved in the evaluation will be provided with tutorials about the implemented system in various formats including audio, video and text. They will then be able to interact with the system and get acquainted with it before evaluating it. The results will be collected and used to draw meaningful conclusions about the effectiveness of the proposed model. An articulation of this testing strategy is presented at the beginning of Chapter 5.

1.6 Research Contributions

This research contributes to e-learning personalisation and disability inclusion through the development of an e-learning system from an ontology-driven and disability-aware model, which addresses the difficulties faced by students with disabilities in accessing current e-learning systems. By designing, implementing and evaluating a disability-aware model for personalised learning, this thesis makes useful contributions to e-learning. The main contributions are as follows:

Development of an ontology-driven and disability-aware model for designing e-learning systems for personalising learning materials. Existing e-learning systems have no effective mechanism for adapting to the learning needs of students with

disabilities particularly those with multiple disabilities whilst considering their learning goals, preferences and disability as well as managing the numerous learning resources. The ONTODAPS model consists of different components, synonymous to a community of agents, each performing specific functions, which, by intercommunicating, bring about an effective personalisation to meet the learning needs of the learner while considering their special needs.

Development of a disability ontology for personalising e-learning for students with disabilities. From searching the web for ontologies to reuse, the author came across no ontology that could be used in its entirety for this study. The ADOLENA ontology was obtained from one of its authors and extended to form the Abilities and Disabilities Ontology for Online LEarning and Services (ADOOLES). Chapter 4 describes the ADOOLES ontology with its various classes and properties.

Implementation of an ontology-driven and disability-aware e-learning system for personalising learning materials for students with disabilities. In order to test the efficacy of the ontology-driven and disability-aware model in personalising learning materials for students with disabilities, an e-learning system called ONTODAPS which identifies the needs of users and presents them with learning materials in a suitable format whilst considering their learning goals and disability type was implemented.

Evaluation of the ONTODAPS model. The ONTODAPS model was evaluated using case studies, heuristic evaluation and experimental evaluation with some students. User evaluation involved students with disabilities interacting with the visual interface and carrying out specific tasks before filling in an evaluation questionnaire. The results of user evaluation suggest that ONTODAPS can provide efficient personalisation for students with disabilities including those with multiple disabilities and that ONTODAPS can provide a means of effectively managing learning materials that may

be found in an e-learning environment. This is very important because some students with disabilities might struggle in browsing through large numbers of learning materials.

Increased access to learning materials. By recommending learning materials in formats that are appropriate for the disability of individuals, this research contributes to increasing access to learning and hence contribution to disability inclusion, in compliance with contemporary disability legislations.

Recommendations for inclusive e-learning system design. By asking students with disabilities what they expect to find in online learning environments that could meet their specific needs and through personal observations during experiments, recommendations were made for designing more inclusive learning environments.

Contribution to literature. This thesis makes a contribution to literature in the field of personalised e-learning for students with disabilities through a review of literature in the field as presented in Chapter 2 and through the publications that have arisen as a result of this research.

1.7 Thesis Outline

This thesis focuses on a review of relevant literature on disability and e-learning personalisation and the difficulties arising from the interaction of students with disabilities within e-learning systems. It also presents the design, implementation and evaluation of an ontology-driven and disability-aware e-learning model for personalising learning materials for students with disabilities. It spans seven chapters with references and appendices. The contents of specific chapters within the thesis are as follows:

Chapter 1, ***Introduction***, provides a general introduction and background to the research, which includes the context in which it is situated as well as its scope. It also provides the motivations for carrying out this research while presenting its hypothesis, aim and objectives, the research questions, its contribution, an overview of the thesis content and concludes with a summary of the chapter.

Chapter 2, ***Personalised E-Learning and Disability***, which is the background to this study reviews literature relevant to this research. It examines issues related to disability and personalised e-learning. The overall purpose of the chapter is to introduce the problem.

Chapter 3, ***Approaches to Designing Learning Environments for Students with Disabilities***, which extends the literature presented in Chapter 2, aims to set the scene for designing and evaluating the ONTODAPS model by examining existing approaches to web-based systems development, including the weaknesses of such approaches, also discusses standards used for annotating learning materials.

Chapter 4, ***An Ontology-Driven Disability-Aware Personalised E-Learning System (ONTODAPS) Model***, aims to provide a solution to the problem raised in Chapters 1 and 2 by presenting the model and architecture of the ONTODAPS system which is used to personalise learning for students with disabilities. The functioning of the ONTODAPS constituent agents is explained. The chapter also presents the ADOOLES ontology and concludes with a summary of the chapter.

Chapter 5, ***Case Studies***, seeks to show how the proposed model works in personalising learning for students by considering the case of a student without disability, a student with a single disability and one with multiple disabilities.

Chapter 6, *Evaluation of the ONTODAPS Model*, which aims to provide statistical data to support the hypothesis, focuses on the evaluation of the prototype e-learning system. This evaluation is done using two methodologies: (i) standard empirical evaluation by users and (ii) heuristic evaluation by experts. To accomplish the evaluation, evaluators are asked to interact with the system based on established guidelines, carrying out specific tasks and to fill in some questionnaires, resulting in the collection, analysis and interpretation of the results. The chapter concludes with a summary of the contents covered therein.

Chapter 7, *Conclusions and Future Research*, seeks to provide the implications of the proposed model through some conclusions of the entire research and its findings. The research objectives are revisited before presenting the contributions of this research and the chapter finally concludes by looking at possible future research arising from this thesis.

1.8 Summary

This chapter has examined the context of this research, situating it in the broader context of personalisation of e-learning for students with disabilities. Whilst technology is widely used in educational institutions, some students with disabilities are disadvantaged, necessitating actions to be taken to include them. The scope of this research was also defined within the research context with this research focusing on personalisation of e-learning materials for students with disabilities. A justification for the research was presented where the need for personalising learning for students with disabilities was established. The chapter also included the research hypothesis, aim and objectives as well as the research questions and contributions. An overview of this thesis content was provided, where the contents of various chapters were discussed, leading to a conclusion of the chapter.

In the following chapter which examines some related work and hence forms the background to this study, various issues related to disability and personalised e-learning will be examined. This will shed more light on the problems arising from students with disabilities using e-learning environments and the need for a new solution.

Chapter 2: Personalised E-Learning and Disability

2.1 Overview

The previous chapter provided a general introduction to this study, introducing the problem this research attempts to solve as well as stating the aim and objectives of this study. This chapter will go ahead to further explore the concept of learning, highlighting various learning theories and styles. As this thesis seeks to provide a solution for the benefit of students with disabilities, disability and education will also be discussed as some common disabilities that are encountered in education will be presented. The way these disabilities affect students will be discussed including the assistive technologies that are employed to support students with disabilities and the shortcomings of these assistive technologies. E-learning will then be discussed, including personalisation and the techniques used to accomplish it. Some personalised e-learning systems will be discussed as will the limitations of current e-learning systems. Overall, this chapter will discuss the problems that were revealed in Chapter 1.

2.2. Learning Theories and Styles

There are several theories that explain how people learn. Amongst these theories, this thesis will discuss behaviourism (Watson, 1930, Skinner, 1974), cognitivism (Piaget, 1973) and constructivism (Thomas et al., 2014, Vygotsky, 1978) since they are directly relevant to e-learning. Although learning styles are not the focus of this thesis, they are worth mentioning as learning styles are frequently being used in personalisation of learning environments by some researchers even though there are some controversies with them. Also, learning styles will be briefly mentioned in the results from heuristic evaluation in Chapter 6.

2.2.1 Behaviourism

Behaviourism holds that the learner starts with a clean state known as *tabula rasa* and the mind responds to stimulus. Thus, this theory operates on a "stimulus-response" principle. In Skinner's operant conditioning (Skinner, 1938), behaviour is modified through positive and negative reinforcements. The thought process is not considered, rather, the focus is on the external stimulus that causes a change in behaviour. Thus, the learner is observed as they react to stimulus. Hence, Behaviourists emphasise more on environmental factors than on the learner (Ertmer and Newby, 2013). For Skinner (1974), "learning is a change in observable behaviour caused by external stimuli in environment". Early e-learning was highly influenced by Skinner as the emphasis of educational technology researchers was on designing an environment to shape behaviour through learner-system interactions (Ravenscroft, 2001).

Demonstrating the conditioning behaviourism theory, Pavlov (1902) studied salivation in dogs when they were being fed. Pavlov found that dogs could salivate in response to hearing the sound of a bell given that the dog could associate the food with the bell. The food served as stimulus that elicited a response (salivation) in the dog. Whenever he gave food to his dogs, he rang a bell which then caused the dogs to associate the bell to the food and thus learned the behaviour of salivating when they subsequently heard the sound of the bell.

Watson was one of those who first made a strong case for behaviourism (Malone, 2014). Watson's (1913) thinking was derived from Pavlov's studies on animals in what is known as classical conditioning. He opposed mentalist concepts of the internal state of an individual because it was not observable and thus subject to subjective interpretation and believed that an individual learns through practice. Thus, for Watson, only behaviour that could be observed, recorded and measured were valuable. On the

other hand, rather than relying on observation, Thorndike used experimental analysis in behaviourism by conducting experiments on "instinctive and intelligent behaviour" (Lattal, 1998).

From an e-learning perspective according to Mödritscher (2006), for the basic concepts, skills and factual information to be rapidly acquired by learners, behaviourists recommend a structured, deductive approach to design an online course. Furthermore, there is the concept of drill and practice, portioning materials and assessing learner's achievement levels, and giving external feedback. Ravenscroft (2001) notes that in designing learning environments after Skinner's operant conditioning, "typically, information was presented in brief chunks, followed by questions and immediate feedback that reinforced correct responses". Skinner's teaching machine which represented behaviourism in educational technology is similar to today's computer programs as educational software helps to reinforce student behaviour (Meegar and Pacis, 2012) .

2.2.2 Cognitivism

Cognitivism seeks to address the limitations of behaviourism. "Cognitive development refers to a mental process by which knowledge is acquired, stored, and retrieved to solve problems" (Gillani and O'Guinn, 2004, Ertmer and Newby, 2013). According to Mödritscher (2006) citing Ally (2004), cognitivists view learning as an internal process that involves memory, thinking, reflection, abstraction, motivation, and meta-cognition.

Regarding the implication of cognitivism for e-learning, Mödritscher (2006) summarises that instructional designers need to chunk the learning content into smaller parts and notes that a major weakness of the cognitive approach is that since it focuses on reaching higher-level objectives it might not be suitable for a learner who lacks the

relevant prerequisite knowledge. However, to compensate for this, the instructions need to be appropriate to all skill levels and experience. This is however costly and time consuming.

Ravenscroft (2001) asserts that an extremely cognitive and individualist approach to interaction design is the paradigm by Jean Piaget (Piaget, 1973) which is commonly referred to as cognitive constructivism. Also mentioned is the fact that "according to Piaget, the child acts on the world, with expectations about consequent changes, and, when these are not met they enter into a state of cognitive conflict or disequilibrium. Thus they seek to retain an equilibrium state and so accommodates unexpected data or experience into his understanding of the context under exploration". Papert (1980) was inspired by the Constructivist ideas of Piaget to develop the LOGO language, enabling learners to create their own "mental models" and microworlds and thus create individual meaning for themselves (Ravenscroft, 2001). Vygotsky however, differs from Piaget in that "studying child thought apart from the influence of instruction, as Piaget did, excludes a very important source of change and bars the researcher from posing the questions of the interaction of development and instruction..." (Vygotsky, 1962). According to Ravenscroft (2001), Vygotsky, a social constructivist made some important points that are relevant to designing e-learning interactions one of which is the fact that "learning, and particularly the development of higher mental processes, requires a cooperative interaction between a student and a more learned other, where the latter may be a human tutor or an intelligent computer system" (Ravenscroft, 2001). Thus, this thesis through an ontology-driven and disability-aware model, seeks to mediate learning for students especially those who might not be able to interact well with learning environments due to disability as discussed in Chapter 4.

2.2.3 Constructivism

Constructivism which evolved from the works of Piaget and Vygotsky, is a "family of related theories" (Efran et al., 2014) which include personal construct psychology, radical constructivism and social constructivism (Raskin, 2002) and originates from the fields of psychology of cognitive development and epistemology (Bachtold, 2013). Constructivism holds that learners interact with their environments and then construct knowledge from such interaction (Ertmer and Newby, 2013). Such construction deals with the mind and if the body is used, it is to "stimulate the active construction of knowledge by the mind" (Bachtold, 2013).

According to Vygotsky (1978), knowledge is constructed socially through communication. Thus, learning takes place because of the individual's interactions. Thomas et al. (2014) assert that constructivism is based on the following assumptions: "learning results from the individual's interaction with the environment; learning is stimulated by cognitive dissonance and the social environment plays a critical role in the development of knowledge". Piaget and Vygotsky also differ in that "in Piaget's theory, the teacher played a limited role whereas in Vygotsky's theory, the teacher played an important role in learning" (Meegar and Pacis, 2012).

If according to this theory learning occurs through interaction and constructing knowledge through the mind, it follows that the learning environment must be designed such that the learner can interact with it and access information without barriers. This means that accessibility barriers need to be removed to allow for full interaction and hence a good learning experience. To support the constructivist approach, e-learning systems need to adapt to the special needs of the learner (Leypold et al., 2004), something which is missing in existing e-learning systems.

Mödritscher (2006) citing Boethel and Dimock (1999), notes amongst the implications for online learning of this theory that: "learners should be given control of the learning process. Besides there should be a form of guided discovery where learners can make their decision on learning goals, but can also use some guidance from the instructor".

This research will promote this learning theory by ensuring the development of an e-learning model which presents learning materials to learners based on their disability type and learning goals, hence enabling them to be able to access the learning materials in formats that are suitable for them. By so doing, they will be able to interact well with the materials and thence gain useful knowledge that will aid their learning. This is in accordance with the Constructivist approach in which "interaction of the learner and the environment creates knowledge" (Ertmer and Newby, 2013).

2.2.4 Learning Styles

Learning styles refer to the learner's preference of learning, and can be visual, auditory or kinaesthetic. Existing learning style models include: Kolb Learning Styles Theory (Kolb, 1985). David Kolb carried out much research into experiential learning, including learning in higher education. Kolb's Experiential Learning Theory (ELT) model describes experiences of the learner. This model is based on four elements: concrete experience, observation and reflection, the formation of abstract concepts and testing in new situations. In this model, concrete experience and abstract conceptualisation are grasping experiences while reflective observation and active experimentation are transforming experiences.

Honey and Mumford Index of Learning Styles (Honey and Mumford, 1992) describes four types of learners: activists learn by doing and enjoy new experiences, reflectors learn by observing and reflecting on what happened, theorists are logical in approach

and want to understand the theory behind actions while pragmatists are very practical in approach.

The VARK model (Fleming, 2001) describes four types of learners: visual learners who have preference for seeing and thus visual aids are very vital for learning; auditory learners who learn best by listening and will thus learn best from materials presented in audio format and through group discussions; reading/writing preference learners who tend to take notes and spend much time reading them in order to synthesize and assimilate the material and kinaesthetic learners who learn well by doing, thus involvement in activities such as experiments, practical demonstrations and interaction with the world are very helpful.

There is a vast amount of research in e-learning employing learning styles for personalisation. Chookaew et al. (2014) offered a personalised e-learning environment to facilitate programming for students by personalising their learning styles, learning achievement and learning problems. In addition to considering the learning styles of the learner, the learner's knowledge level is also considered (Dwivedi and Bharadwaj, 2013). These are just two examples of researchers using learning styles to provide personalisation, more of which are discussed under e-learning personalisation in Section 2.5.

As mentioned in the overview of this chapter and in Section 2.2, learning styles have been criticised, for instance, Kolb's learning style has issues with the scoring method, particularly the test retest reliability, Honey and Mumford's questionnaire is not psychometrically robust (Coffield et al., 2004). Nevertheless, Ravenscroft (2001) notes that "although the concept of learning styles may be considered problematic, in that it cannot clearly predict consequences, it points out that students have preferred methods of interaction , and ideally, an e-learning system should accommodate this". As already

mentioned in Section 2.2, this thesis does not directly deal with learning styles but will be briefly mentioned in the heuristic evaluation results in Chapter 6.

2.3 Disability and Education

There are an increasing number of students with disabilities in educational institutions worldwide (Poore-Pariseau, 2010). These students with disabilities usually require some support either in the form of mentoring, note taking, and examination support or through the provision of assistive technology to facilitate learning. Disability can affect learning; this is the case with some common forms like dyslexia. However, with the move to e-learning and increasing use of technology, those with visual impairments may be left behind if care is not taken to improve accessibility. This section will discuss what disability is, some common forms of disability encountered in education and how they affect learning, including the accommodations that are being made to support learning for students with such disabilities.

2.3.1 What is Disability?

Disability refers to some physical or mental impairment to an individual which prevents them from carrying out their normal activities. Physical impairments may affect the senses such as sight (visual impairment), hearing (hearing impairment) and movement (upper and lower limbs mobility difficulties) while cognitive impairment (e.g. dyslexia, dyscalculia, dysgraphia) may directly affect learning.

2.3.2 Prevalent Disabilities in Education

HESA (Higher Education Statistics Agency) statistics (HESA, 2012) over the years show that Specific Learning Difficulties (e.g. dyslexia, dyscalculia, etc.) are the most common declared disabilities. On the other hand, Kelly and Smith (2008) observe that students with visual impairments such as those using screen readers appear to be more

disadvantaged than students with other disabilities. This is evident from the problems encountered by visually impaired people when trying to browse inaccessible websites with screen readers.

2.3.2.1 Visual Impairments

Various terms have been used to describe people with visual impairments, including partially sighted, low vision, totally blind and legally blind. A person with severe visual impairment will not normally be able to see even with eyeglasses, contact lenses, medicine, or surgery. Mainly, visual impairment such as congenital blindness is caused by diseases attacking the eye such as cataract, glaucoma and macular degeneration. Low vision refers to “any chronic visual impairment that affects every day functioning and is not correctable by glasses or contact lenses” (Kalia et al., 2008).

A big challenge that students with visual impairments face is that most of the materials used in science-based courses are visual whereas the main sensory channels of these students are tactile and auditory (Li et al., 2011, Jones et al., 2009). Jones et al. (2009) note that “most learners use visual images to build mental representations of the science involved. However, for those without vision the process of creating mental representations must emerge from haptic (touch with kinaesthetics) and auditory perceptions”. Nevertheless, Jones et al. (2009) citing Cornoldi and Vecchi (2000) further note that “there is evidence that congenitally blind individuals are able to create mental images without visual perception”. Such perception can come about when those who design learning environments take into consideration the needs of the learner with visual impairment and thus design such that they can access the information and thus assimilate the information. Visual impairment appears to have more effects on an individual’s development than hearing impairment. In a study of 81 rubella children with visual and/or hearing impairment, it was noted that “vision has a greater impact on their development than hearing impairment or prenatal variables such as low birth

weight" (van Dijk, 1983). Visual impairment negatively affects learning. It has been shown that visual impairment is correlated with poor learning and memory performance in visuo-spatial tasks but not in tasks that depend on visual cues (Wong and Brown, 2013).

As e-learning technologies require a significant use of the senses of sight and hearing, without the availability of assistive technologies, people with visual impairments could be disadvantaged. To prevent such discrimination, visual resources such as video, PowerPoint slides, text-documents, diagrams and illustrations will need to be presented in alternative formats such as Braille or audio for blind users or large print for those with low vision or partial sight; for them to access the same information. Otherwise, appropriate assistive technologies will need to be employed.

Some solution to the problems encountered when accessing resources on the current web lies on new technologies that can enable more meaningful access to information for visually impaired people and in this light, research is on-going. The semantic web, a "new form of web that is more meaningful" (Berners-Lee et al., 2001) is one of such solutions to the problems encountered by people with visual impairment online. The efficacy of the semantic web in providing such solution has been proven through practical implementations. Salampasis et al. (2005) used semantic web technologies to facilitate web browsing for blind people. This involved using the technologies to create annotated web pages and also to develop an annotated browser which exploits the annotations to semantically enhance browsing. Lorenz and Horstmann (2004) also used semantic web technologies such as the resource description framework (RDF) to grant blind people access to graphically represented information by semantically annotating the graphical information with RDF.

Similarly, the semantic web could be positively used to manage learning materials and improve their accessibility for visually impaired students through semantic annotation and retrieval, thus, helping to solve the problems faced in trying to browse through the huge number of resources on the web.

2.3.2.2 Specific Learning Difficulty

Specific learning difficulties (or disabilities) cover a wide range of difficulties including dyslexia, dysgraphia (difficulty with writing), dyspraxia (motor difficulties) and dyscalculia (difficulties with mathematical calculations).

Amongst the disabilities found in further and higher education, dyslexia is the most common (Dunn, 2003a, Snowling, 2001). **Dyslexia** is defined by the International Dyslexia Association (IDA) as:

“a specific learning disability that is neurological in origin, characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities” (IDA, 2011).

Thus to provide any meaningful personalisation for students with dyslexia, an e-learning system will need to analyse their needs whilst taking into consideration all the difficulties these students face with e-learning and thence presenting learning resources in formats that facilitate understanding and retention.

On the other hand, **dyscalculia** is defined as:

“a condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning number facts and procedures.” DfES (2001).

Recent research has shown a deficit in fundamental aspects of mathematics such as sets amongst elementary school children with dyscalculia (Butterworth et al., 2011). For children aged between 3-5 years, early intervention to facilitate mathematical learning could be very beneficial and effective in the long run (Clements and Sarama, 2011). Similarly, in a higher education context, by providing effective personalisation of e-learning, the students' learning difficulties might be alleviated.

The Dyspraxia Foundation defines **developmental dyspraxia** as:

“An impairment or immaturity of the organisation of movement. It is an immaturity in the way that the brain processes information, which results in messages not being properly or fully transmitted. The term dyspraxia comes from the word praxis, which means 'doing, acting'. Dyspraxia affects the planning of what to do and how to do it. It is associated with problems of perception, language and thought”. (DyspraxiaFoundation, 2011).

People with **dyspraxia** may have difficulty with reading, writing and spelling, with poor handwriting being one of the most common symptoms of the disability. In early years, speech may be immature or unintelligible. People with this impairment may also have difficulty with organising their thoughts, have poor short term memory and are easily distracted.

Dysgraphia is characterised by a difficulty with handwriting, which may be illegible with irregular and inconsistent formation of letters or could be legible but very small. Dysgraphia is not linked to intellectual impairment.

Given the increasing occurrence of learning difficulties amongst students in education, an inherent trend, and given the drive for wider participation, it is worth seeking various solutions that can enhance their learning and access to specific learning materials.

Current research has shown that the semantic web could offer solution to the problems faced by people with disabilities through personalisation (Kadouche et al., 2008) and increased accessibility (Kouroupetroglou et al., 2006, Moreno et al., 2005). In education, semantic technologies such as ontologies could be used to develop applications that will support students with dyslexia in their learning. In this light, a personalised e-learning environment will be very helpful to such students. Schmidt & Schneider (2007) and Tzouveli et al. (2008b) developed an adaptive reading assistance for learners with dyslexia using semantic web technologies. This application which uses ontologies and has integrated voice recognition was developed for primary school pupils. In a higher education context however, the requirements and application may be different. Additionally, this application only focused on pupils with dyslexia, leaving the need for an e-learning system which is inclusive of all disabilities and can provide a personalised experience to its users based on recognition of their needs and goals as expressed in their individual profiles.

2.3.2.3 Hearing Impairments

Hearing impairment refers to the loss of hearing in one or both ears, which could be complete or partial. People with hearing impairments will have specific requirements such as captioning for video and audio. When audio and video learning materials are presented in learning environments online without transcripts or captions, the content becomes inaccessible and hence they may not be able to understand the information, which can negatively impact on learning outcome.

2.3.2.4 Mobility Difficulties

Mobility and dexterity difficulties which could also be referred to as physical impairments may be acquired or congenital in origin and affect individuals in a variety of ways. Such difficulties could be characterised by problems with sitting for long

periods or slow movements which in some cases could be painful, resulting from injury or amputations, arthritis or spinal cord injury for example. Some students with mobility difficulties will need to use wheelchairs or electric scooters. Mobility difficulties are not only limited to the lower limbs, but also affect the upper limbs and this could make using the mouse and keyboard difficult for such people. Alternative input devices such as joysticks could be used. Higher education institutions will need to provide tables that are accessible using wheelchairs as well as ramps, where this is needed.

Research into developing systems for people with mobility difficulties is on-going in the EU. The EU funded project ASK-IT (Ambient Intelligence System of Agents for Knowledge-based and Integrated Services for Mobility Impaired users) uses semantic web enabled services to support and promote the mobility of mobility impaired people. This is done by enabling the provision of personalised, self-configurable, intuitive and context-related applications and services as well as facilitating knowledge, content organisation and processing (Cabrera-Umpierrez et al., 2007).

When building semantic web systems, developers will need to allow for compatibility of such systems with assistive technologies. Requirements to facilitate compatibility will need to be defined; similar to how requirements for web page accessibility for blind people are defined. RDF (Chapters 3 and 4) annotations of these systems could be able to allow for recognition of alternative input devices. The needs of people with mobility difficulties will also need to be incorporated into semantic web learning environments.

2.3.2.5 Mental Health Difficulties

It is estimated that 1 in 4 people of the adult UK population will experience some form of mental health problem. Mental health difficulties range from mild depression to acute schizophrenia. Other common mental health difficulties include psychosis, anxiety (including panic attacks), attention deficit disorder, obsessive compulsive disorder, self-

harm and eating disorders (such as anorexia nervosa, bulimia nervosa and binge eating disorder). Agoraphobics avoid crowds and hence public places and would thus benefit from personalisation of services online.

The semantic web also offers solutions to solve problems related to mental difficulties. Coyle and Doherty (2008) have described the potential of using ontologies in the development of interactive systems to support mental health interventions. Their system emphasises psychoeducation, shared peer content and stories and adaptability. The ontology described there is specific for use by clinicians and care workers to diagnose and provide support to those with mental health problems but also allows for elements such as learning models and interaction preferences/requirements to be incorporated in the ontologies.

In the education context, the mental health ontology will need to be specific for learning services, containing the special educational needs of people with mental health difficulties.

2.3.3 Assistive Technologies in Education

In education, the presence of some forms of disability requires the use of technology to compensate for the impairments. A student with visual impairment for instance might need a screen magnifier or screen reader to read course notes on a computer. Depending on the disability, individuals will need personalised information in specific formats. This section will discuss some types of assistive technologies employed in education to help solve the difficulties encountered by some students with disabilities and the issues facing their use in e-learning environments.

2.3.3.1 Assistive Technologies for Students with Visual Impairments

Students with visual impairments have a wide range of assistive technologies available to them, depending on the severity of the impairment. An assistive technology is a device or system that is used by people with disabilities to facilitate tasks that may be impossible or difficult to perform as a result of their disability. These range from screen magnifiers for those with partial sight to screen readers and refreshable Braille for those with congenital blindness. Again, there are numerous technologies available but this thesis will explore a few commonly used ones.

A. Screen Magnifiers

Screen magnifiers are used by people with low vision to increase the size of content displayed by the screen and to focus on desirable areas of the screen. Students with visual impairments can use these to aid their reading of learning materials online. Much research has been done on screen magnifiers; for instance, Blenkhorn et al. (2003) presented the architectures of some screen magnifiers and presented driver and system-based magnification as two approaches to implement screen magnifiers on Windows systems. Zhao et al. (2009) used some principles in visual search theory to design and develop a screen magnifier, recommending the use of a yellow background for a magnifier when the text is black.

As screen magnifiers mainly magnify information to visually impaired people, they may not have a similar accessibility problem as those encountered by screen readers.

B. Screen Readers

Screen readers, a form of text-to-speech software are used by blind people to read text-based content. The software works by reading the content out loud to the user. A more in-depth study on screen readers and other speech-enabled devices has been carried out by Freitas and Kouroupetroglou (2008). Students with very low vision or who are blind

can use screen readers to read online content and this technology has been found to be very popular amongst visually impaired people. In a phone survey amongst 80 visually impaired people in Turkey, Bengisu (2010) found that screen readers were the most used assistive technology. Screen readers browse through websites and when they encounter an image, they read the description contained in the ALT or LONGDESC attributes of the IMG tag. These tags are part of the Hypertext Markup Language (HTML) used to design websites (Nganji et al., 2013a). Alternative texts are therefore very necessary to include when presenting images on the web so that screen readers could tell users what the image is. However, when no description is provided or in the case where such description is incorrect, the visually impaired person using a screen reader may not be able to understand the description of the image. A setback of using ALT or LONGDESC is that the ALT attribute only provides a short description of images while LONGDESC which could provide a longer description is not supported by some browsers and assistive technologies (Petrie et al., 2005). This calls for the use of cutting edge technologies such as web ontologies to comprehensively describe images for assistive technology interoperability and interpretation to visually impaired people (Nganji et al., 2013a).

C. Refreshable Braille Display Device

Braille provides tactile reading and writing for people with visual impairments (Chakraborti et al., 2012). Such devices provide information to the user by stimulating the sense of touch (Lee and Lucyszyn, 2005). A Refreshable Braille display device is an electronic device which is a tactile reading aid providing improved computer accessibility by translating text that has been visually displayed on a computer monitor into tactile Braille cells (Yobas et al., 2003). The refreshable Braille device produces a Braille output of the information that is displayed on the computer monitor. Refreshable Braille displays are very advantageous in that they can improve information

accessibility for visually impaired individuals whereas the traditional "Braille text on paper deteriorate very quickly and are very bulky, and therefore difficult to store and transport" (Vidal-Verdu and Hafez, 2007).

2.3.3.2 Assistive Technologies for Students with Dyslexia

There are many assistive technology products available for students with a specific learning difficulty to use in order to enhance their studies. This section will focus on some common ones available to students with dyslexia.

A. Homophone Tools

Homophone (Lange et al., 2009) and specific spelling tools such as Read&Write (Texthelp, 2014) help readers and writers with learning disabilities such as dyslexia by helping to improve their reading and writing. Homophones have been found to be helpful to students with reading difficulties as well as those with weak reading skills (Lange et al., 2009). Text-to-speech systems also help students with reading difficulties by converting text on a computer system into synthesized speech (Draffan et al., 2007).

B. Diagramming Tools

Diagramming tools such as Inspiration (McKenzie, 2003) facilitate visual mapping, outlining, writing and making presentations. Inspiration's diagram and map views facilitate understanding of ideas and thoughts. Diagramming tools are also useful for Computer Science students involved in computer programming. In a study by Lee et al. (2008), some participants revealed that diagramming tools could be helpful in exploring a code base when they are new to the code. Computer science students with learning difficulties could therefore use Inspiration and other diagramming tools to plan their programming activity in a way that will facilitate both their understanding and their implementation of the software they intend to develop. SUMLOW (Chen et al., 2008) a Unified Modelling Language (UML) diagramming tool could also be used by students

with disabilities to sketch UML constructs and is thus particularly helpful for students studying databases.

2.3.3.3 Assistive Technologies for Students with Hearing Impairments

For people with hearing impairments, assistive listening devices (ALDs) such as hearing loop (or induction loop) can amplify sound. The hearing loop consists of the source of the sound which can be a microphone, telephone, TV, etc.; an amplifier, a thin loop and a receiver which is worn by the user in the ears. The receiver can also be a headset. ALDs are effective in managing hearing loss (McInerney and Walden, 2013). For children with dyslexia, it has been found that ALDs can improve neural representation of speech and impact reading-related skills (Hornickel et al., 2012). Despite the perceived benefits of using ALDs, usage remains low in older populations (Hartley et al., 2010).

Augmentative and alternative communication (AAC) devices such as touch screens with symbols or pictures work by helping people who have communication disorders to express themselves. AACs are generally classified as aided AAC which involves devices or equipment or an unaided AAC that does not require an external device (Gevarter et al., 2013). AACs can improve an individual's communication and the ability to participate in interactions (Hagan and Thompson, 2014). Although AACs have many benefits for people with communication needs, the potential of AACs remains unrealised for many individuals with complex communication needs (Light and McNaughton, 2014).

2.3.3.4 Assistive Technologies for Students with Mobility Difficulties

Permanent mobility difficulties of the arms could result from spinal cord injury, resulting in quadriplegia which is a paralysis of the legs and arms. Some individuals with this paralysis might not be able to use the mouse or a keyboard. Mobility difficulty

resulting from cerebral palsy also affects how individuals interact with computers. Other diseases such as Parkinson's disease, arthritis and multiple sclerosis also affect an individual's use of the computer.

For such individuals with motor difficulties, there is a wide range of assistive technologies that can enable them to interact with computers. Those who cannot control hand movements well can rely on adaptive keyboards (Fitrianie and Rothkrantz, 2007) while eye tracking devices (Hwang et al., 2014) enable those who do not have any control of the mouse with their arms, to interact with a computer. As the individual looks through the screen, the device follows the eye movements and hence enables the individual to browse the web. Voice recognition software (Williams et al., 2013) when installed on the computer allows individuals to interact with the computer through speech.

2.3.3.5 Assistive Technologies for Students with Mental Health Difficulties

Assistive technologies can help people with mental health difficulties in areas such as helping to calm them down and also with remembering information. Devices such as mobile phones can serve as reminders for appointments. Apart from the use of technology to support people with mental health difficulties, the use of humans as support workers can be very effective. These basically provide support for such people and can help calm them down when anxious and also help with organisation and planning. Mentors can also work to support students with mental health difficulties in classrooms as is the practice at the University of Hull.

2.3.4 Assistive Technology Difficulties

Although assistive technologies have been discussed in the previous section, this section has been reserved to examine the difficulties encountered in using assistive technology in e-learning environments and possible solutions to these difficulties.

2.3.4.1 Failure of Assistive Technologies

Although assistive technologies greatly enable learning for students with disabilities, these technologies themselves can be a disabling factor if not properly integrated into student learning. A big problem thus results from a mismatch between the assistive technology and the e-learning system which in turn results in some difficulty with using the device within the e-learning environment; as a result, the student may not be able to achieve their learning goals if they cannot access the learning materials which in some extremes could lead to academic failure. As Tompsett (2008) notes:

“Poor integration of some e-learning and virtual learning environments with some assistive technologies such as screen readers can significantly degrade the productivity and achievement of some students with disabilities”.

Even when an assistive technology is successfully integrated into an e-learning environment, another problem may arise which lies in its use. Given that disability is an individual experience and may vary from one person to another, the experience of a student with a specific disability may change over time, requiring an update of the technology. If this is not done, the e-learning environment may have an assistive technology which is useless. E-learning systems therefore need a mechanism of adjusting to the assistive technology needs of students and this could be inferred from the student's profile.

It was noted earlier that some screen readers at times are unable to read information contained in the ALT or LONGDESC attributes of the IMG tag due to incompatibility or lack of inclusion of such attribute. This problem arises from the fact that screen readers tend to read things rather superficially, at the non-semantic topmost layer of the web where HTML sits, rather than at the deeper level of the semantic web where ontologies are used to represent knowledge and provide more meaning for both

machines and humans to understand the information that is presented. Thus, some assistive technologies like screen readers tend to depend on other platforms such as the web, Windows, MAC, etc., in order to function effectively, and are not able to work independently. Consequently, these assistive technologies will depend on the structure (architecture or model) of these applications and hence, in the event where the structure is faulty, information will not be correctly conveyed to the user as earlier seen with screen readers browsing inaccessible HTML pages and not being able to relay any meaningful information to visually impaired users.

2.3.4.2 Possible Solutions

The problems faced by using assistive technologies with e-learning environments could be resolved by integrating such technologies directly into the learning environments. However, this is also a problem since numerous issues arise as earlier discussed. The technology needs to adjust to the changing needs of the user.

It is imperative to look for new ways of integrating assistive technologies with e-learning environments and developing novel architectures which are disability-aware and can help solve the problems associated with the shortcomings of existing architectures. This research partially responds to these needs through a novel architecture for personalising learning materials for students with disabilities, following a disability-aware model for designing e-learning systems.

2.4 E-Learning

E-learning does not have a specific definition that is widely accepted but generally refers to learning or instruction with technology. According to Bell and Federman (2013), there are many other terms that are used to refer to the same concept. These terms as used by other authors include: online learning (Shea and Bidjerano, 2014), modern technology-based distance learning (Thoms and Eryilmaz, 2014, Robertson,

2014), computer-assisted instruction (Weng et al., 2014), computer-based instruction (Weng et al., 2014, Ozkan et al., 2013), technology-based instruction (Ross et al., 2009), technology-delivered instruction (Mancuso-Murphy, 2007, Sitzmann et al., 2009), computer based simulation (Sanguino et al., 2014) and simulation games. Cox (2013) considers e-learning as “technology-enhanced learning and information technology (IT) in teaching and learning”. E-learning usually includes self-study activities (Lewis et al., 2014).

In contrast to e-learning, traditional learning involves a lecturer standing in front of students and delivering materials in the classical "chalk and talk" manner. Thus, students meet at a specified place and time to participate in lectures that are given by a lecturer, participate in group discussions, laboratory sessions and to take examinations. In such settings, it is easier to ensure participation and to enforce discipline in the classroom, something which is difficult to achieve in e-learning (Wang, 2011). As Severance (2013) notes, in on-campus courses, students can be required to "learn a lot outside of the lectures and still meet deadlines that come quite quickly", something which "does not translate well to the MOOC (Massive Open Online Course) experience". There is also a high dropout rate in e-learning (Condruz-Bacescu, 2013). E-learning can only be feasible where the resources are available. Hence, it is disadvantageous where there is a lack of infrastructure (Cakmak and Yilmaz, 2014). This is the case in some developing countries which are resource poor and may not have the technology required to run e-learning courses or where the quality of the resources is not good enough to implement e-learning. For instance, low bandwidth will inhibit a good learning experience while the digital divide (Nganji et al., 2010) where there is shortage or complete absence of the required technology further ensures exclusion of those who cannot afford to buy such technologies that are often expensive to them. In such settings, traditional learning is the best option. Where there are fewer technological

resources, it could still be possible to implement blended learning, a method of learning where traditional methods of education are combined with the use of technology (Allan, 2007). With this, there could also be challenges including the possibility of excluding people with disabilities (Nganji and Nggada, 2014).

Although e-learning has some disadvantages, its advantages far outweigh these disadvantages, hence there is an increasing use of e-learning as many universities worldwide are now adopting and using e-learning (Lin et al., 2014, Bharuthram and Kies, 2013, Bell and Federman, 2013, Fichten et al., 2009a) at an exponential rate (Sadeck, 2013). Teachers are also being encouraged to develop e-learning materials (Vermeulen et al., 2012). Whilst traditional learning is bound by space and time as students are confined to a specific lecture room for a set period of time, e-learning does not suffer from such constraints (Wang, 2014). With the explosion of the web in this information age where there is a lot of information, online learning is now greatly facilitated in online social spaces as learners also engage in collaborative learning (Coll and Engel, 2014). The increasing availability of computers whether in cars, as tablets, phones and other portable devices makes e-learning and mobile learning (m-learning) more accessible. The increasing adoption of mobile phones in developing countries (Olla and Choudrie, 2014) shows the great potential for implementing mobile learning in such countries. This has the potential of facilitating learning as users engage with these technologies daily and use them to interact with others and share ideas. In fact, Moazami et al. (2014) found e-learning to be more effective than traditional learning amongst dental students.

Whilst traditional learning cannot accommodate significant increase in student numbers such as having several students registering and taking a particular course due to a lack of the required physical space to accommodate huge numbers of students, an alternative

has arisen in online learning known as Massive Open Online Course (MOOC). MOOCs offer "video lectures, computer graded tests and discussion forums" (Hoy, 2014). Whilst MOOCs are growing and have the potential to grow further, Clarke (2013) remarks that they still have the challenge to "resolve other issues e-learning organisations have faced including assessment, high dropout rates, and how to maintain viability". The concern of how to ensure accessibility for students with disabilities also raises significant challenges for MOOCs and needs to be addressed if such courses would be fully inclusive. That said, many higher education institutions are successfully implementing MOOCs and when the existing challenges are addressed, this could lead to a good learner experience.

According to Zhang et al. (2006), e-learning has the benefit of unrestricted access to electronic learning material. It has a lot to offer to students with disabilities in the area of increased access to learning materials when learning materials and environments are designed accessibly and also offer a means of adapting to the needs of the learner. Thus e-learning can be used to present learning materials to students with disabilities in adapted forms that are suitable for them (Power et al., 2010). A visually impaired student such as one with blindness may not be able to view PowerPoint slides when presented in a lecture hall but in an online environment, they can be able to use assistive technology to read and understand the content. A student with hearing impairment may not understand a lecture when there is no interpretation in the classroom but in the online learning environment, when an audio or video of that lecture is accompanied by captions or transcripts, the student will be included. Students with dyslexia can also benefit from the addition of audio and videos of lectures online where they can be able to access in their own time and can play, pause and move back to specific sections of the lecture with enough time to interact with it and understand the lectures. As said

earlier, all such resources need to be designed with accessibility in mind, thus being disability-aware.

2.4.1 E-Learning Environments

In educational institutions, e-learning is typically delivered through virtual learning environments such as Blackboard (Bradford et al., 2006), Moodle (Carvalho et al., 2011), Sakai (Caminero et al., 2013, Yang and Allan, 2007a), Desire2Learn (D2L, 2014) and more recently, Canvas (Canvas, 2014). These are systems which enable educators to create and deliver courses, including managing the courses and users. In literature, such learning environments are sometimes referred to as learning management systems (LMS) or course management systems.

Blackboard is a web-based course management system that supports online learning and teaching. Blackboard features include discussion boards, online quizzes, virtual chat, journals and blogs amongst others. In response to legislation to protect the rights of people with disabilities, accessibility and usability were incorporated to include all users by supporting the use of assistive technologies. However, there is no in-built assistive technology which comes with this product, meaning students with disabilities requiring assistive technology have to acquire and use their own assistive technologies with the e-learning environment. Blackboard has been made accessible to people with disabilities following the guidelines from Section 508 of the US Rehabilitation Act (Jaeger, 2006) and the Web Accessibility Initiative (WAI). However, Blackboard does not provide any mechanism for adapting to the needs of learners with disabilities. Thus, there is no means of personalising the learning materials to suit the disability type.

Sakai is a Java-based open source collaboration and learning environment developed by the Sakai community that provides users with a suite of learning, portfolio, library and

project tools. It is made up of a set of software tools which have been designed to help instructors, researchers and students collaborate online. Sakai includes features such as live chat, discussion board, online testing, assignment uploads and email amongst others. Although Sakai is similar to Blackboard and other VLEs, it incorporates a lot more tools such as web conferencing and calendaring. Just like Blackboard, Sakai does not have an integrated assistive technology to meet the needs of some students with disabilities. Also, this does not offer any means of adapting to the needs of students with disabilities.

Moodle is also another learning environment which is used in many higher education institutions worldwide. This is an open source learning environment that enables institutions to deliver and manage courses. A lot of research has been done into the accessibility of Moodle (Calvo et al., 2012) and researchers have tried to produce accessible and personalised versions (Laabidi et al., 2014). This thesis will revisit Moodle in more detail in section 2.6.1 in the light of its specific support for disabilities.

Canvas (Canvas, 2014) is a more recent learning management system which allows students to integrate their accounts with social media platforms such as Twitter and Facebook. It also has a grade book which enables students to see their grades for individual assignments and their overall grade. Thus through personalised mobile and social notifications, it updates students on their progress.

2.5 Personalised E-Learning and Techniques

The sheer size of the internet means that there is a fundamental issue of being able to see the woods for the trees - there is thus a need to target and order information. One approach to solve this problem of accessing the overwhelmingly numerous resources and information on the web is through personalisation, which makes it a lot easier for individuals to access relevant information. Web personalisation involves tailoring

content to meet the needs of users and is usually based on the user's online profile. The need for personalisation stems from the fact that individuals have differing needs and preferences (Choi and Han, 2008). One of the reasons why different learners have different needs and preferences is because of disability (Nevile and Treviranus, 2006). By understanding these user characteristics, information can be tailored to their needs, thus facilitating retrieval.

In personalisation, content can be presented to a user based on what their interests are and could be obtained from their previous browsing patterns. In e-learning, personalisation is a very effective and efficient means of meeting a learner's needs and enables them to achieve their goals faster (Nadolski et al., 2009). It is also understood that personalised learning can lead to improved motivation (Childress and Benson, 2014).

Much work has been done on e-learning personalisation on the existing non-semantic web (Conlan et al., 2002, Alonso et al., 2005, Mor and Minguillon, 2004). As the web evolves into the semantic web, there is need for such personalisation to be implemented using semantic technologies due to the potential to produce intelligent agents that would meet the needs of people with disabilities. Such personalisation using semantic web technologies will be very useful to students with disabilities given that semantic technologies add meaning to web content and thus facilitate information search and retrieval. Various researchers have developed systems for personalising learning on the semantic web (Dolog et al., 2004b, Wen and Jesshope, 2004, Wen and Brayshaw, 2007, Wen, 2008), but very little has been done in the area of e-learning personalisation for students with disabilities on the semantic web. Just like with most technologies encouraging the "disability divide" (Hollier, 2007), researchers appear to be widening

the gap in the field of semantic web research in special needs as relatively little research is being done in the domain of the semantic web for people with disabilities.

With the presence of the semantic web, personalisation will be improved as semantic technologies will provide more meaning to resources. According to Vallet et al. (2005), personalisation is all the more necessary for situations such as when there are large amounts of available content, the user has short time, when there are imprecise needs and when new content is available.

2.5.1 Types of Personalisation

Personalisation could target different aspects of a system based on the needs of the user. This section reviews some of the most common types of personalisation.

2.5.1.1 Content Personalisation

With information overload, information can now be readily made available to users through personalisation, specifically content-based personalisation. Content personalisation usually involves presenting users with contents that are suitable to their preferences (Schewe et al., 2009, Koutsabasis and Darzentas, 2008) which are usually based on the user's profile. Content personalisation has also been achieved with mobile devices (Paireekreng and Wong, 2010, Moldovan and Muntean, 2009).

2.5.1.2 Link/Navigation Personalisation

With the numerous options present on the Web, the challenge for some users who may not be good at browsing is which links to click on. This is made especially difficult in the case where web designers do not use meaningful link names or when they use confusing ones. Information retrieval through browsing web links can be facilitated by providing meaningful link names and also personalising web links. The latter involves facilitating navigation through presenting users with links that are more relevant to them

(Longpradit et al., 2006, Longpradit et al., 2008). Such personalisation is particularly common with e-commerce websites such as Amazon.com (Liang et al., 2009).

2.5.1.3 Presentation Personalisation

This form of personalisation involves presenting users with different look and feel depending on their preferences (Tvarozek et al., 2007, Garrigos et al., 2009). Takealook is a system that personalises information presentation to users based on individual interests and knowledge (Sumi et al., 1999, Sumi et al., 2000). For people with disabilities, presentation personalisation is particularly useful as it will facilitate access to information. Students with dyslexia for instance might prefer information presented to them in a specific format such as audio, rather than very long text, or for such textual information to be kept short but containing the relevant information that could be read in a shorter period of time without compromising the main message. People with visual impairments on the other hand might prefer audio resources to visual ones due to the difficulties of following visual cues on the web; and hence could be presented with information in that format. In personalising presentation, system implementations also need to consider multiple disabilities and to intelligently personalise information for such complex cases.

2.5.2 Personalisation Techniques

As already mentioned above, personalisation is usually based on a user's profile. Such profile captures the user's preferences, interests and other characteristics that enable a system to present information that is relevant to them. The information could be presented based on some filtering techniques. This section deals with the two methods of user profiling and information filtering but does not claim to cover all aspects of both techniques.

2.5.2.1 User Profiling

User profiles capture facts about the user usually containing essential information about the user often without the person's explicit consent (Aimeur et al., 2010). The profile usually contains information regarding the user's interests and preferences (Reformat and Golmohammadi, 2010), goals, knowledge, behaviour and background. User profile contents can be obtained from the user providing such information through filling forms or answering questionnaires but in some cases is also obtained through inferences from the user's browsing patterns. NewsDude (Billsus and Pazzani, 1999) for instance, collects information about users' long term and short term interests through the news articles they browse. User profiling has been achieved using semantic web technologies with Hopfgartner and Jose (2010) using Linked Open Data Cloud to identify similar news stories that match users' interest.

2.5.2.2 Information Filtering

The problem of information overload could be tackled with information filtering techniques where information recommendation methods are used. This section covers the main information filtering techniques.

A. Rules Engine

Information filtering using rule-based techniques allows rules to be specified based on a user's profile (Gao et al., 2010). Rules for instance could be specified to present students with disabilities with learning materials in a format that is suitable to their specific needs such as presenting audio rather than video for a visually impaired student or providing an interface that allows a user with upper limbs mobility difficulties to use onscreen keyboards rather than the conventional keyboards, based on their user profile.

B. Content-Based Filtering

Content-based filtering recommends information to users by comparing the contents of the information with the user's profile. This type of filtering becomes ineffective when

the keywords used do not accurately represent the contents of items. Content-based filtering follows various approaches including probabilistic (Naphade and Huang, 2001, Vasconcelos and Lippman, 1998) and Bayesian approaches (Zhang and Guan, 2009).

C. Collaborative Filtering

Collaborative filtering recommends information to users based on the ratings of other users (Braida et al., 2015, Ju et al., 2015). According to Yang et al. (2008), the feedback from the user can either be explicit (through rating) or implicit (interacting with the item through clicking to make a decision about the item). Since collaborative filtering depends upon the user rating, there will be no recommendations to a user if there are no ratings. The accuracy is poor when there is little data.

D. Hybrid Approach

Hybrid filtering systems (Burke, 2002) combine the techniques of different types of filtering such that the strength of one compensates for the weakness of the other (Burke, 2005). Both content-based filtering and collaborative filtering have some disadvantages explained above and the hybrid approach seeks to provide a solution by combining aspects of these approaches (Cantador et al., 2008, de Campos et al., 2010). Hybrid filtering however faces problems of scalability and sparsity (Choi et al., 2010). News@hand (Cantador et al., 2008) is an example of a hybrid recommendation system.

2.5.3 Ontology-Based Personalisation

The success of personalisation in e-commerce shows its potential to be employed in other domains. It was noted earlier that semantic web technology, particularly ontologies, could help solve some of the problems faced by the current web. According to Bergman (2007), ontologies can provide a more effective basis for information extraction. In ontology-based personalisation, web ontologies drive the personalisation and ontologies could be used to develop the user's profile to provide an effective

personalisation. Ontology-based web personalisation has been successfully achieved in news recommendation (Cantador et al., 2008), recommending learning materials (Liu et al., 2010) and in route planning (Niaraki and Kim, 2009), just to name a few. Unfortunately, ontology-based personalisation is not being exploited enough for the benefit of students with disabilities. Such personalisation is achievable as has been the case with Tzouveli et al. (2008b) who used web ontologies to provide an adaptive reading assistant for pupils with dyslexia.

2.5.4 Personalised E-Learning

Traditional learning environments provide a one-size-fits-all approach to learning usually with the teacher determining how learning proceeds. However, this has greatly changed and is resulting to changing roles for the teacher (Shaikh and Khoja, 2014). Thus personalised learning is a radical shift from the traditional approach and seeks to tailor learning to suit the needs of the learner (Childress and Benson, 2014, Thalmann, 2014, Hsieh et al., 2013). Personalisation of e-learning is gaining increasing attention due to the benefits associated with it. When an e-learning environment is personalised, the learner is able to interact more personally with the environment because it takes into consideration their needs. It is easier to find information in a personalised learning environment than one where the user needs to use experience to find where information is stored. By understanding the learner's past activities, search results can be more precise, thus helping in providing specific content (Zhuhadar et al., 2008).

In personalising learning, there is an emerging concept, that which defines a new way of learning and creating the environments for learning. This involves collaborative learning in social space, directed by learners. This is known as personal learning environments where students are encouraged to design their own learning environments (Valtonen et al., 2012). Although this will encourage students to be involved and active

in the learning process, they will often need guidance from experts. To accomplish personalisation, researchers tend to use the learner's profile to provide the learner with specific learning materials (Tzouveli et al., 2008a). Personalisation based on user profiling (Tzouveli et al., 2008a, Biletskiy et al., 2009, Kritikou et al., 2008) also focuses on predicting the preferences of the users and then personalising or adapting the e-learning environment based on those preferences.

E-learning personalisation also involves the learning styles of the learner (Klasnja-Milicevic et al., 2011, Pukkhem and Vatanawood, 2011). Such personalisation involves analysing the user's interaction with the system and then collecting information regarding the user's interests as well as their knowledge levels and learning styles in order to provide them with personalised learning content. Research in personalising learning has also focused on the influence of dialect in multimedia narration (Rey and Steib, 2013). Whilst personalised learning focuses on either e-learning or m-learning, advances in personalisation includes the integration of the two (Nedungadi and Raman, 2012).

Personalising e-learning also involves considering the user's needs. To recommend relevant material, the system needs to consider the learner's profile and the type of learning material (Roy et al., 2009). To provide a successful personalised environment, Thalmann (2014) produced a set of 13 adaptation criteria to enable delivery of learning materials. Amongst these are content adaptation to meet the preferences of the learner and the media format. This research will employ these two criteria by presenting learning materials to users in either video, audio or text based on their disability type.

There is an increase in the development and use of digital learning materials in virtual learning environments. The significant increase in learning materials makes finding them difficult. Personalising the learning environment helps to solve the problems of

locating the correct learning materials from a vast repository of learning materials (Salehi and Kamalabadi, 2013). These learning materials are not only text but could include videos, photos, slideshows, audio, etc. (Little et al., 2012).

Some authors have produced recommender systems which recommend learning materials to learners based on filtering techniques (Ghauth and Abdullah, 2010). By knowing the learning styles of the learner, researchers are now able to recommend appropriate learning materials (Halbert et al., 2011). The semantic web has also been successfully used to provide recommendations based on the user's profile (Nasraoui and Zhuhadar, 2010).

The production of simplified language materials which use shorter words and sentences, with fewer clauses, and less negative and passive forms (Rix, 2009) is something that could be beneficial for students with dyslexia. For the materials to be usable, some researchers have suggested that an iterative approach be used during development where usability testing is carried out (Davids et al., 2014).

2.5.4.1 Personalised E-Learning Environments

E-learning personalisation involves presenting students with learning materials and services in a package that is suitable for their personal needs. This could be based on their learning goals or preferences or both.

A. The EU4ALL Project

The European Unified Approach for Accessible Lifelong Learning (EU4ALL) project (Douce et al., 2010) constitutes a framework to personalise e-learning and learning services to users based on their preferences and needs. The system constitutes a virtual learning environment, a user modelling system, a content personalisation system, metadata repository system, a recommendation system and a device modelling system.

The EU4ALL project works within an existing VLE such as Moodle and provides personalisation for students.

When a learner interacts with the VLE and requests a learning resource, this request is passed on to the content personalisation system which queries the user profile to present the appropriate resource to the user.

A recent approach to user profiling proposes the use of the learner's supporting human and technological agents to determine the learner's access needs rather than the author of the e-learning system determining these needs (Cooper and Heath, 2009).

The approach used in the EU4ALL has a significant influence on the way in which the ONTODAPS model in Chapter 4 will be designed, by considering the personalisation of e-learning and its services to users based on their needs and preferences. However, the ONTODAPS model will be more inclusive as it will address the needs of learners with multiple disabilities.

B. Adaptable Personal Learning Environment (APLE)

Just like EU4ALL, the Adaptable Personal Learning Environment (APLE) adapts to the needs and preferences of a learner but also provides personal choice of systems and tools (Pearson et al., 2009). In APLE, the learner's profile is managed using the Profile for Adaptable Learning (PAL) tool. User preferences are described in terms of visual, aural or device and can be used to tailor learning content to the learner. To produce the user profile, PAL enables the user to choose from given adaptability statements. The user needs and preferences are compared with the resource components to provide the user with personalised resources.

Just like in APLE, the ONTODAPS model that will be presented in Chapter 4 will also enable learners to manage their profile. This is very important given that ONTODAPS

seeks to meet the needs of learners with multiple disabilities. Thus, if a learner has one disability and develops another in the future, ONTODAPS will enable them to add the new disability to their profile and for the system to respond to their new needs based on the updated information. Whilst APLE does not deal with the needs of learners with disabilities, the idea of users managing their profile can be of great help to those with disabilities in an e-learning environment.

C. The <e-aula> E-Learning Platform

Sancho et al. (2005) proposed the use of semantic metadata for the contextualisation of Learning Objects to adapt learning in the <e-aula> e-learning platform based on background knowledge, learning goals and learning style of the learner. This personalisation is achieved by breaking down courses into modular units.

User modelling techniques are also employed to adapt the learning content to fit the user context. This system makes use of the pedagogical ontology and the context of the domain knowledge ontology. With the information provided by the ontologies and the user profile, the system creates a personalised course for the learner.

Although the above platform is not specific for learners with disabilities, the idea of using semantic metadata to enable content adaptation is very useful as discussed in Chapter 3 and will be used in the ONTODAPS model.

D. Other E-Learning Systems

The personalisation by Gomes et al. (2006) uses SCORM (Sharable Content Object Reference Model) for content development and implementation of a student model. The student model acts as the user's profile and contains personal data which could be static and not altered as the student interacts with the system or could be dynamic and hence changes as the student progresses in their learning. The dynamic model makes use of an ontology to provide personalisation by making reference to course concepts which form

the basis of the decision on what contents should be shown to the learner (Pah et al., 2008).

This approach uses two types of personalisation: online in real time using a reasoning engine to infer on the adaptations that are needed and offline personalisation which collects data relating to the student and the system and analyses them to recommend course content changes (Gomes et al., 2006).

2.6 Personalised E-Learning environments for students with disabilities

This section reviews some personalised e-learning systems which have been implemented for the benefit of students with disabilities.

The MoodleAcc+ e-learning system was designed to respond to the need for accessibility in e-learning systems. It consists of four tools: learner assistance tool, author assistance tool, accessible course generation tool and platform accessibility evaluation tool (Laabidi et al., 2014). The learner assistance tool allows learners to edit their preferences and also allows learners to select their disability type. The system allows learners to select their preferences regarding display, control and content. However, the tool does not allow for learners with multiple disabilities to select more than one disability type. The accessible course generation tool generates personalised learning materials based on information contained in the learner's preferences. So, the system can present a user who has hearing impairments with a video containing captions rather than presenting them with a video without captions. Thus, this system functions using filtration. The author assistance tool enables the author to include accessibility metadata in the learning materials. The accessibility evaluation tool enables the system to test if the web content or learning environment is accessible.

The disabled-friendly learning environment was built for students with blindness, deafness, speech disabilities and cerebral palsy (Kyung Ng, 2013). The e-learning system is mainly made up of a web-based multi-media system with video conferencing and voice recognition. The system also has a chat system to enable students with hearing impairments to communicate with others. In this system, the lecturer delivers a lecture which is then streamed online and then a speech recognition system converts the speech into text which is then displayed on the screen of the user. On the other hand, students with blindness listen to the lecture using head phones or built-in speakers. It is worth mentioning that this system is not only for students with disabilities but students without disabilities also study alongside those without disabilities. In this system, every student receives information in text, video and audio formats.

Whilst this system is useful in that it provides learning materials in multiple formats (text, video, audio), it does not really personalise the information. Learning materials will be presented and the student can then choose their preferred format.

2.7 Issues with Current E-Learning Environments

Existing e-learning systems have various limitations which make it difficult for students with disabilities to use when the issues are not resolved. Existing e-learning systems in universities such as Blackboard and Sakai are very limited in the way they adapt to the needs of students. For e-learning environments to meet the needs of the learner, they need to be adaptable, with the student being able to change their preferences and edit information in their profiles. Nevertheless, current learning environments do not offer enough adaptation to meet the needs of learners (Peter et al., 2010, Tompsett, 2008, Devedzic, 2004). It is therefore difficult for such systems to respond to the needs of students with disabilities as the content is usually designed for everyone without students with disabilities in mind.

Learning environments also suffer from the problem of inaccessibility due to inaccessible learning materials or due to inaccessibility of the e-learning systems themselves (Fichten et al., 2009b). As Fichten et al. (2009b) suggest, the problem can be due to content put into the learning environment and to the e-learning software. The software problem mostly arises from the fact that developers use traditional software development methodologies which often do not lead to accessible or usable systems for people with disabilities (Nganji and Nggada, 2011). Thus, Nganji and Nggada (2011) proposed the use of a disability-aware approach where the needs of the learners are considered throughout the process in consultation with the users, by extending traditional software development iterative methods in order to produce an accessible and usable system. Laabidi et al. (2014) agree that accessibility needs to be incorporated from the beginning of the software development life cycle. Davids et al. (2014) further suggest that an iterative process of development needs to be used which includes usability testing. Some of the content of e-learning systems are inaccessible because the content authors do not design with accessibility in mind. Hence, some multimedia such as video and audio are not captioned and are inaccessible to those with hearing impairments (Fichten et al., 2009b). E-learning accessibility refers to how accessible e-learning is for people with disabilities. It is ensuring that people with disabilities are not prevented from access because of their disability (Seale and Cooper, 2010). When well implemented, e-learning can facilitate the inclusion of students with disabilities such as visual impairments in classrooms (Fichten et al., 2009a). To ensure that e-learning is accessible to people with disabilities, their needs have to be considered.

Another serious shortcoming of most e-learning systems that are built for students with disabilities is that they often only focus on a specific user group (Sampson and Zervas, 2011). Guenaga et al. (2004) noted that e-learning systems need to adopt a design for all approach, such an approach considers all disabilities and Fichten et al. (2009a) agree to

a universal design approach. Nevertheless, this is not the case with existing e-learning systems built for people with disabilities. Most products tend to want to solve the challenges faced by specific disabilities, forgetting that an individual may have multiple disabilities. The learning environment by Schmidt & Schneider (2007) and Tzouveli et al. (2008b) for instance only focus on pupils with dyslexia, while the learning environment by Drigas et al. (2006) focuses on students with sight disabilities. As mentioned earlier, although the learning environment by Laabidi et al. (2014) is designed for accessibility and allows users to customise content by selecting their disability type, it does not allow for the selection of multiple disabilities and personalisation for multiple disabilities. The problem of how to personalise for students with multiple disabilities has not been addressed in existing e-learning systems and remains a challenging one for e-learning environments. This confirms the assertion by Petrie et al. (2006) that it is difficult to design for multiple disabilities.

Most learning environments used in higher education institutions do not offer inbuilt assistive technologies such as a screen magnifier or screen reader which could be activated by the reader based on their disability. If such technologies are incorporated into learning environments, they will help to solve the incompatibility issues faced by assistive technologies.

Even when learning environments are designed with accessibility in mind, students with disabilities may still have difficulties finding the correct and relevant learning materials if the learning environment is not flexible enough to allow for adaptation by the learner based on their needs and preferences. Usually, adaptation is achieved based on information in the user profile. Often, the user profiles do not contain any information on the user's disability status, which makes it difficult to adapt to the special needs of the learner in addition to their learning needs. When adaptable, the learning

environment can then be used to personalise learning materials for the learner and to present materials that are suitable for their specific needs, taking into consideration their disability type and learning needs. To this end, this research will make a contribution through a disability-aware e-learning model.

2.8 Summary

This chapter has provided the background to this research. It began by looking at some learning theories and learning styles. The chapter then went on to examine some types of disabilities that affect students in education and the assistive technologies available to help students with these disabilities.

In response to one of the research questions of this thesis, it was seen that personalisation is a means of increasing access to learning materials. As this thesis adopts personalisation to deliver to the personal needs of students with disabilities, personalisation and the techniques used to achieve it were discussed, before some existing e-learning environments employing these techniques as well as the use of ontologies for personalisation were presented including their limitations. In analysing the limitations of existing e-learning systems, it was seen that most learning environments are not adaptable enough and do not consider the needs of students with multiple disabilities. The need for novel approaches to designing these systems and novel models which permit a more effective personalisation, including handling cases of multiple disabilities whilst providing an effective management of the vast array of learning materials, was raised. The following chapter will present approaches used in designing learning environments for students with disabilities, including standards for annotating learning materials.

Chapter 3: Approaches to Designing Learning Environments for Students with Disabilities

3.1 Overview

In Chapter 2, the concept of learning was discussed, including learning theories and styles. The subject of disability was also discussed, including some of the disabilities commonly encountered, how they affect students and some assistive technologies used by students with disabilities to enhance learning. Personalisation was discussed, including the techniques used in personalising learning environments. Chapter 2 also revealed problems with existing learning environments such as inadequate adaptation to meet the needs of learners (Peter et al., 2010, Tompsett, 2008, Devedzic, 2004), inaccessibility to most learners with disabilities because they are designed inflexibly (Pahl, 2003) without considering the needs of such learners (Fichten et al., 2009a) and are often designed for a specific target user group (Sampson and Zervas, 2011), hence not being inclusive of all learners.

Some of the above problems arise from the approach used in designing the learning environment. This chapter will thus examine the methodologies used in developing learning environments specifically with the aim of responding to the needs of students with disabilities. It also discusses the various standards used in annotating learning materials to facilitate retrieval and personalisation. By dealing with these issues, this chapter, which extends the literature in Chapter 2, will set the scene for developing the ONTODAPS model in Chapter 4.

3.2 Approaches to Systems Design

Many authors of the information on the web have no knowledge of accessibility or the browsing needs of people with disabilities. The consequence is information that is difficult to access even with some assistive technologies. This problem also exists amongst those who have had some form of training in systems design and development. In some methodologies common to software development, there is a requirements analysis phase where the needs of potential users are analysed, to provide a user-centred or inclusive design. The difficulties arising from inaccessibility could be traced back to the root which in this case is the method used for development.

Several models have been proposed for designing applications; the following section reviews some of them.

3.2.1 Object-Oriented Approaches

One of the earliest object-based models for designing hypermedia applications is the OOHDM-Object Oriented Hypermedia Design Model (Schwabe et al., 1996). This method describes hypermedia-based navigation by an object model on three levels, the conceptual level, the navigational level and the interface level (Schmid and Herfort, 2004, Schmid and Donnerhak, 2005). While this model provides simple navigation of information, the complex process involved in storing, processing and presenting data and the very high costs associated with using this model are its major weaknesses. Additionally, this does not focus on meeting the needs of the user.

On the other hand, the Enhanced Object-Relationship Model (EORM) (Lange, 1996) is based on three frameworks: Class framework, Composition framework and the GUI framework and mainly functions in providing relationships between objects. OOHDM and EORM make use of various scenarios at domain analysis to project object modelling and navigational design. The problem with these approaches is that they still

produce applications that are not accessible to people with disabilities because they do not emphasise an analysis of the needs of end users.

3.2.2 User-Centred Approaches

This section will examine user-centred approaches to designing systems beginning with user-centred design, moving to inclusive design and finally examine the newer and more inclusive approach known as user-sensitive inclusive design.

3.2.2.1 User-Centred Design

User-centred design has been around since the eighties with Norman (1988) and the nineties with authors such as Nielsen (1993) and Helander (1997) amongst others who are nowadays encouraging design to meet the needs of people with disabilities. User-centred design has the aim of putting the user at the centre of a design process so that the end product can meet their needs. During this process, designers try to predict how users will interact with the product and try to solve the problems that may arise in the course of using that product. However, if inadequate information about the user is collected by designers, the resulting environment will be incompatible (Altay, 2014). Gasson (2003) argued that such methods fail to promote human interests because they focus on "the closure of predetermined, technical problems". Newell and Gregor (2000a) argue that in product research and development, users should be involved but not have a dominant role.

3.2.2.2 Participatory Design

Just like user-centred design, the participatory or cooperative design (Muller et al., 1996, Muller, 1996, Muller and Kuhn, 1993, Kyng, 1991) seeks to involve all stakeholders of the project during the design process as designers meet with users and other stakeholders so that the end product does not only meet their needs but is also

usable to them. Blomberg and Henderson (1990) characterized Participatory Design as "advocating three tenets which influence the character of the interaction between developers and users of computer-based systems" as:

- The goal should be the improvement of the quality of work life of the users
- Orientation should be toward collaborative development
- The process should be iterative.

As with the object-oriented approaches to designing web systems, most of the above methods do not work well for people with disabilities. Thus, Gregor et al. (2005) have noted that most of these approaches do not provide sufficient guidance on how to design for both older people and people with disabilities.

3.2.2.3 Inclusive Design

Inclusive design (Hyponnen, 1999) has arisen to fill the gap created by other approaches. This seeks to meet the needs of a wide range of users including people with or without disabilities (Goodman-Deane et al., 2014). One of the business cases for inclusive design is that increasing ageing populations lead to growing opportunities for inclusive products (Waller et al., 2015). Waller et al. (2015) also suggest that inclusive design needs to be considered throughout the development process. In order to prevent inaccessibility, Ohene-Djan and Shipsey (2008) suggest that learning technology should include architectures in which adaptive content form, adaptive interaction and adaptive presentation can be driven by a "user model of inclusion". However, as a criticism of inclusive design, Newell et al. (2010) have noted that such approaches do not work well for older people and people with disabilities as "by paying 'lip service' they may design systems that are accessible but not usable for older people and people with disabilities". They thus propose a user sensitive inclusive design approach which involves the

potential users in the process. The model that will be presented in Chapter 4 of this thesis will include modelling learners with and without disabilities such that the information from their profiles can be used by personalisation agents to offer effective personalisation of learning.

3.2.2.4 User-Sensitive Inclusive Design

Newell and Gregor (2000b) and Newell et al. (2010) propose a User-Sensitive Inclusive Design to include older people and people with disabilities. They consider “inclusivity” more achievable than “Universal Design” and “Design for All”. This design recommends that designers develop an “empathetic” relationship with the users (older people and people with disabilities) rather than only requiring them as “subjects” for experiments to test the usability of their products. A form of user sensitive inclusive design that is more specific for people with disabilities is the disability-aware approach (Nganji and Nggada, 2011) depicted in Figure 1 which primarily emphasises the inclusion of users with disabilities throughout the product development cycle in addition to consulting experts. As this specifically focuses on designing for people with disabilities, this approach will likely result in greater accessibility and usability of the end product although it might be costly to involve many stakeholders in the process.

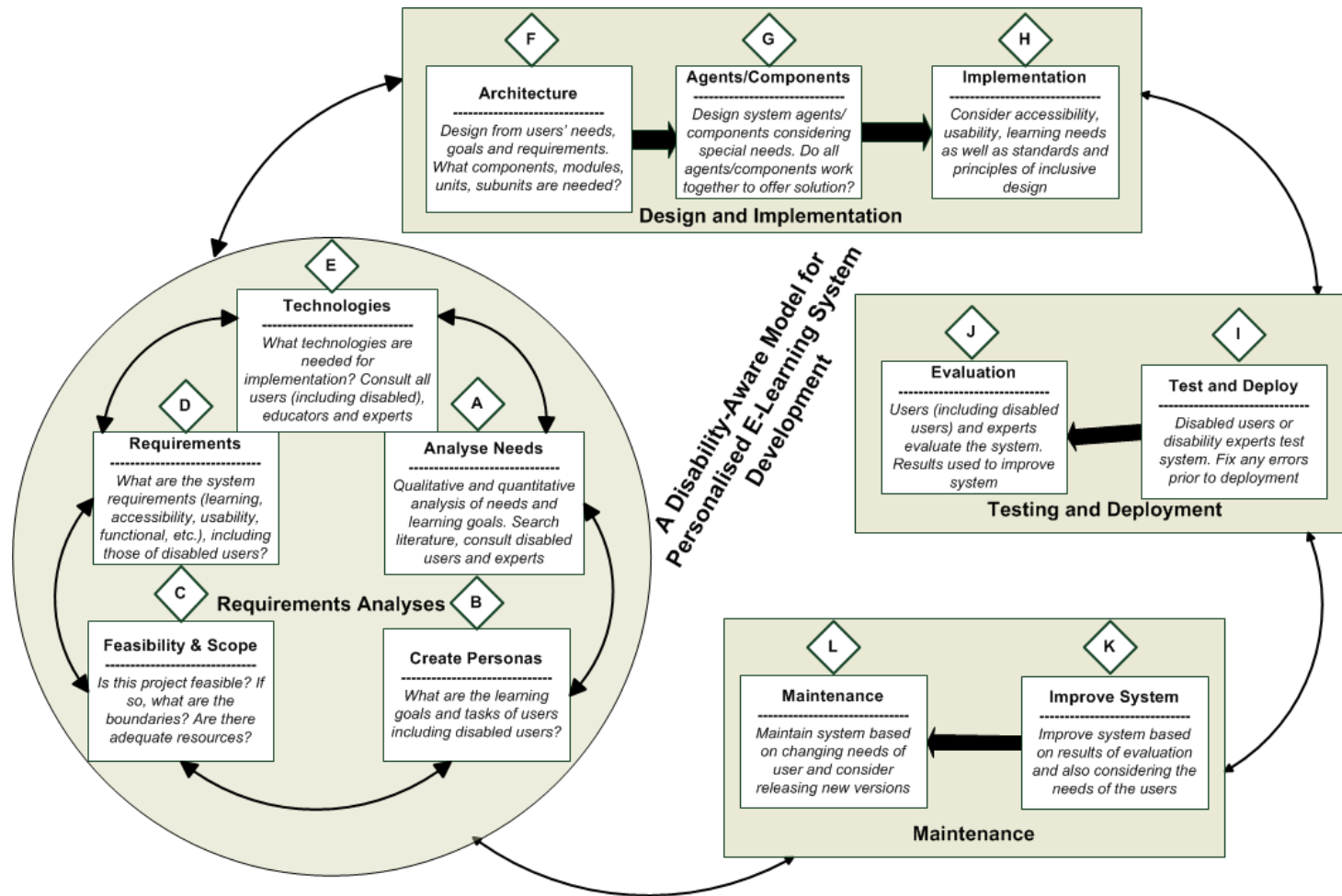


Figure 1. A Disability-Aware Personalised E-Learning System Development Approach

3.3 Standards for Describing Learning Materials

There are various standards for describing information on the web. This section discusses metadata standards, including semantic web standards and the associated technologies that can be used to describe resources on the web in order to facilitate search, retrieval and presentation.

3.3.1 Metadata Standards

Metadata standards for e-learning are formal specifications used to semantically annotate educational materials of any kind (Al-Khalifa and Davis, 2007). Metadata refers to data properties (Kogalovsky, 2013), "data about data" (Dagger et al., 2003, Sugimoto et al., 2002) or "machine understandable information about Web resources or other things" (Liechti et al., 1998). There exist several standards for describing learning content with metadata. One of the most popular is the IEEE Learning Object Metadata Standard (IEEE LOM) which enables reuse of learning objects. The IMS Learning Design (IMS-LD) specification also enables the sharing of learning designs across learning environments.

3.3.1.1 IEEE LOM

The IEEE Learning Object Metadata Standard (IEEE LOM) is one of the main specifications for learning object metadata (Zervas and Sampson, 2014). Developed specifically for the educational domain (Aroyo et al., 2003), it is a popular way for describing digital resources, however, it cannot meet specific requirements and the particular needs of different educational communities (Sampson et al., 2012). According to Balatsoukas et al. (2011), IEEE LOM is an important predicate for the successful implementation of e-learning systems in UK higher and further education. LOM is an important standard for sharing and reusing learning materials (Ochoa et al., 2011). The limitations of IEEE LOM in handling reusability of learning objects have been

acknowledged (Mohammed and Mohan, 2006). This leads to the need to use ontologies for describing the structure, content, teaching and learning strategies of learning objects (Mohan and Brooks, 2003).

3.3.1.2 SCORM

The Sharable Content Object Reference Model (SCORM), an initiative of the ADL (Advanced Distributed Learning Network) (Rockley et al., 2002) is an extension of LOM, IMS Learning Resource XML Binding Specification and Simple Sequencing Definition Model, the Dublin Core Metadata Initiative vocabularies and the AICC Computer Managed Instruction (CMI) data model (Dagger et al., 2003). It is an international standard for managing learning materials (Jeong and Hong, 2013). Its fundamental objectives are the easy portability of learning content from one Learning Management System (LMS) to another as well as the reusability of learning objects (Bohl et al., 2002). Ildefonso et al. (2013) consider SCORM to be the most important standard for e-learning content. It enables the description and reuse of learning content.

3.3.1.3 Dublin Core Metadata Initiative (DCMI)

The Dublin Core which began in 1995 is a set of fifteen elements (Table 1) for cross domain resource discovery with simplicity, extensibility and semantic interoperability being the fundamental technical characteristics of its development (Sugimoto et al., 2002). The Dublin Core educational version is one of two widely accepted metadata standards in education (Al-Khalifa and Davis, 2007).

Table 1. Fifteen Elements of "Simple Dublin Core" (Sugimoto et al., 2002).

Identifier	Definition
Title	A name given to the resource.
Creator	An entity primarily responsible for making the content of the resource.
Subject	The topic of the content of the resource.
Description	An account of the content of the resource.
Publisher	An entity responsible for making the resource available.
Contributor	An entity responsible for making contributions to the content of the resource.
Date	A date associated with an event in the life cycle of the resource.
Type	The nature or genre of the content of the resource.
Format	The physical or digital manifestation of the content of the resource.
Identifier	An unambiguous reference to the resource within a given context.
Source	A reference to a resource from which the present resource is derived.
Language	A language of the intellectual content of the resource.
Relation	A reference to a related resource.
Coverage	The extent or scope of the content of the resource.
Rights	Information about rights held in and over the resource.

3.3.1.4 IMS AccessForAll Meta-data Specification

The AccessForAll Specifications/Standards provide a common language for describing resources and a common language for specifying learner needs and preferences

(Treviranus and Roberts, 2008). They are not yet an international standard but might soon be. They are used for matching resources to learner needs. The AccessForAll metadata specification is intended to make it possible to identify resources that match a user's stated preferences or needs, declared using the IMS Learner Information Package Accessibility for LIP specification which has been extended for accessibility in the Accessibility Learner Information Package (ACCLIP) (Norton and Treviranus, 2003). According to Treviranus and Roberts (2008), an important approach of the ACCLIP specification is that it is not disability-centric. Instead of assuming preferences based on stated disability, the ACCLIP specification assumes that any learner will have different access preferences depending on any number of factors: their location, bandwidth, access device and subject of study to name a few.

In trying to implement ACCLIP in the ATutor LMS, Mirri et al. (2009) found the following issues:

Learners can explicitly declare in their profile only one alternative access modes for each form of resources but does not allow further choices. A blind user for instance might request audio files describing images, but if such alternatives are absent, he/she cannot choose a text description instead (to be read by the screen reader).

The standard does not deal with sizes or quality of video and audio resources. It is not possible to request a degraded version of a clip or an audio file to be adapted to the device being used.

3.3.2 Issues with Metadata Standards

Jovanović et al. (2007) noted that "specifications/standards such as IEEE LOM and IMS-LD do not enable capturing all the information required for advanced learning services, such as personalisation or adaptation of content in accordance with the students' objectives, preferences, learning styles, and knowledge levels". Recker and

Wiley (2001) also found that such standards are not suitable for personalisation. Stojanovic et al. (2001) assert that such metadata standards lack formal semantics and that although they enable interoperability within domains, they introduce the problem of incompatibility between disparate and heterogeneous metadata descriptions or schemas across domains. They further suggest that this problem can be avoided by using ontologies as a conceptual backbone in an e-learning scenario. The restriction of not being able to capture semantics is also echoed by Dagger et al. (2003).

3.4 Semantic Web Standards

With the shortcomings of metadata standards and limitations in use to provide personalisation in e-learning environments, e-learning systems are increasingly adopting a semantic metadata approach (Al-Khalifa and Davis, 2006) an example being the case with Jovanović et al (2007). Similarly, Dolog et al. (2004a) used RDF meta-information to annotate learning resources as well as represent information about the learner and courses, facilitating adaptation. Devedzic (2004) suggested that by using semantic markup of educational material, learners can readily query the semantic web for educational material and pedagogical agents can find relevant materials. This is something that will be very useful when dealing with the difficulty of adapting learning environments for learners with disabilities, particularly those with multiple disabilities and with matching the learners to the correct learning materials. Devedzic (2004) further suggests that to enable pedagogical agents to automatically search, locate, retrieve, filter, and present educational material to the user, educational services, user group constraints and preferences (such as interests and specific course levels) and agent procedures need to be marked up semantically. Lytras et al (2003b) suggest that a semantic approach to learning technology will help to:

- Implement more intelligent software agents in order to help the learner to find and use globally distributed learning resources.
- Provide personal annotation of any learning resources.
- Make reuse of learning material through RDF transformations in Learning Objects.

Stojanovic et al. (2001) suggest three ways of using ontology-based metadata to annotate learning materials such as:

- Describing the *content* of learning materials (classification to facilitate the retrieval of a specific learning material).
- Describing the *context* of learning materials (educational/pedagogical e.g. presentation context to facilitate searching of specific learning materials).
- Describing the *structure* of learning materials (relational e.g. *IsRequiredBy*, *IsPartOf*, etc.).

3.4.1 Semantic Web Technologies

The semantic web (Berners-Lee et al., 2001) is made up of the following layers:

Unicode and URI: This is responsible for encoding characters and uniquely identifying resources on the internet. Unicode is the standard for computer character representation while URIs provide the standard for identifying and locating resources.

XML: The XML layer with its namespace and schema ensures the use of a common syntax on the semantic web. This layer allows structuring of data on the web but does not communicate the meaning of the data.

Resource Description Framework (RDF): The RDF layer enables the representation of metadata about web resources. It uses URIs to identify web-based resources but also has a graph model for describing relationships between resources.

Ontologies: An ontology is "an explicit specification of a conceptualisation" (Gruber, 1993). The ontology layer provides description for properties and relation between these properties and resources. The Web Ontology Language (OWL) is mainly used for developing ontologies. According to Stojanovic et al. (2001), ontologies usually consist of definitions of concepts relevant for a domain, their relations, and axioms about these concepts and relationships.

Logic and Proof: This is an automatic reasoning system on top of the ontology structure to make new inferences.

Trust: This is the final layer of the semantic web which focuses on issues of trust on the semantic web.

Semantic technologies add more meaning to the web especially with the use of RDF and ontologies (Horrocks, 2008). It is worth examining some semantic web technologies.

3.4.1.1 XML

About a decade ago, XML was the most widely used language to support web-based applications (Farkas et al., 2005). Although XML, a common foundation for emerging metadata formats (Liechti et al., 1998) does not add much meaning as discussed above, Stojanovic et al. (2001) noted that the meaning of XML-documents is intuitively clear, due to semantic mark-up and tags, which are domain terms, but computers do not have intuition. Thus, XML can only act as a "transport mechanism" but not a solution for propagating semantics on the Semantic Web. XML prescribes a standard for embedding descriptive markup within a document and a method for describing the document's

structure (Guerrieri, 1998). Its main purpose is thus to provide a mechanism to mark-up and structure documents (Klein, 2002).

3.4.1.2 RDF

The Resource Description Framework (RDF) can be used to add semantics to a document with information being stored in the form of RDF statements which are machine understandable (Stojanovic et al., 2001). Unlike XML, RDF better facilitates interoperation due to its data model that can be extended to address sophisticated ontology representation techniques (Decker et al., 2000). On the importance of RDF in search and retrieval, Lassila (1998) notes that its focus on machine-understandable semantics has the potential for saving time and yielding more accurate results.

3.4.1.3 DAML+OIL

The DARPA Agent Markup Language (DAML) (2000-2006) was developed as an extension to XML and the Resource Description Framework (RDF). DAML+OIL (Horrocks, 2002) is a markup language for Web resources and combines features of DAML and OIL (Ontology Inference Layer). DAML+OIL was superseded by OWL (Web Ontology Language). However, "practical algorithm for the full DAML+OIL language has yet to be developed, and it is not yet clear that sound and complete reasoners can provide adequate performance for typical web applications" (Horrocks, 2002).

3.4.1.4 OWL

OWL (Web Ontology Language) is a language for the semantic web developed by the W3C Web Ontology Working Group (McGuinness and van Harmelen, 2004). OWL is a revision of the DAML+OIL ontology language and is an extension of RDF/S (Resource Description Framework/Schemas) (Zuo and Zhou, 2003). OWL has three sub languages: OWL Lite, OWL DL and OWL Full. OWL Lite supports users needing a classification hierarchy and simple constraints. OWL DL supports those users who want

the maximum expressiveness while retaining computational completeness and decidability. OWL Full is meant for users who want maximum expressiveness and the syntactic freedom of RDF with no computational guarantees. OWL is more commonly developed using various editors. OWL describes the structure of a domain in terms of properties and classes (Zuo and Zhou, 2003).

3.4.2 OWL Editors

OWL editors such as SMORE (Semantic Markup, Ontology and RDF Editor) enable users to markup HTML documents in OWL using Web Ontologies. As discussed in Section 4.5.1, Lytras et al. (2003b) suggest that "a Java platform which follows an XML communication standard, through web services, is an ideal solution for designing a system which can be adopted easily". Another OWL editor, Protégé (Knublauch et al., 2004), developed at the University of Stanford is an ontology editor and knowledge acquisition system which is free and open source. This has been designed to support ontology modelling via the protégé-frames or protégé-OWL editors. This Java-based platform supports several plugins amongst which is OWL Viz which makes use of GraphViz for graphically displaying ontologies. The ontologies can be output in various formats, including OWL, RDF and XML (Chapter 4). For this research, Protégé was used to develop the ontology described in Chapter 4.

3.5 Summary

This chapter has presented some approaches that are used to design systems to ensure that they meet the needs of the users. An important approach is the inclusive design approach with a recent paradigm being the user sensitive inclusive design which is supposed to be more achievable. A form of such approach which is specific for people with disabilities is the disability-aware approach.

In order to allow for access, interoperability and usability of learning materials, various standards have been developed. Whilst many of these standards such as LOM, SCORM and Dublin Core have been successfully used to develop applications, they have a number of limitations. According to Stojanovic et al. (2001) and Dagger et al. (2003), these standards lack formal semantics which lead to incompatibility issues. A suggestion is to use ontologies in order to avoid such problems. This chapter also discussed the semantic web and the technologies that can be used to describe resources such as web ontologies that have been successfully used in implementing many applications.

The following chapter will build on knowledge from Chapter 2 and 3 to build an ontology-driven and disability-aware model for personalising learning materials for students with and without disabilities.

Chapter 4: Ontology-Driven Disability-Aware Personalised E-Learning System (ONTODAPS) Model

4.1 Overview

Chapter 2 revealed that existing learning environments amongst other shortcomings are not designed to include the needs of students with disabilities, especially those with multiple disabilities. Additionally, there is limited research in the area of personalising e-learning for the benefit of students with disabilities particularly employing cutting edge semantic web technologies. Chapter 3 considered the various approaches used in developing learning environments for students with disabilities and concluded that a user sensitive inclusive approach such as the disability-aware approach will be inclusive of all learners. Also, various standards for describing learning materials were considered and concluded that the best approach will be to employ semantic web technologies in describing learning materials and in modelling information about the user and the courses. The importance of ontologies in e-learning and some examples of how this has been applied were earlier considered in Chapter 2. This chapter will thus focus on developing an ontology-driven disability-aware personalised e-learning system (ONTODAPS) model to facilitate personalisation of learning materials for all students.

4.2 Recap of Findings from Literature Review

This section will present the major findings from the literature review in order to support a framework for personalising learning materials for students with disabilities that will be presented in section 4.4. The major issues that arise when designing e-learning for students with disabilities include: the difficulty of designing for all disabilities (incorporating the special needs of all learners in the learning environment

as opposed to focusing on a single disability) and presenting the learner with the correct learning material that is appropriate for their needs. Designing for all disabilities does not imply a one-size-fits-all approach, rather, it is designing the learning environment flexibly with the ability for it to adapt to the needs of each individual.

4.2.1 Designing for Multiple Disabilities

In Chapter 2, the literature review indicated that most e-learning systems are not designed with enough adaptability to meet the needs of learners (Peter et al., 2010, Tompsett, 2008). This inflexibility was earlier reported by Pahl (2003) who noted that "educational systems are often designed and developed without change and evolution in mind". The current need for learning environments as Tompsett (2008) notes is that of making the learning environment both an assistive and a good learning environment by ensuring that it can be adapted to meet the special needs of the learner whilst also meeting their learning needs.

Nevertheless, a number of learning environments designed to meet the needs of learners with disabilities tend to focus on the needs of those with specific disabilities (Sampson and Zervas, 2011). However, the needs of all learners could be considered when approaches such as user-sensitive inclusive design (Newell et al., 2011) approach are considered which seeks to design products that will meet the needs of people with disabilities.

The model that will be presented in this chapter will thus seek to adapt to the needs of learners based on their disability types. By considering the special needs of the learner, this disability-aware model will be in line with the user sensitive inclusive design approach. This approach does not seek to be a one-size-fits-all as this is not feasible. In fact, Henze et al. (2004) advice to move away from such an approach and provide learners with "individual learning experiences".

4.2.2 Matching the Learner with the Correct Learning Materials

Given that in existing learning environments the needs of those with disabilities are not often considered (Fichten et al., 2009a), the problem of presenting the learner with the correct format of learning materials arises as well. To match the correct learning material to the correct individual also means that such materials should be present in the learning environment. Often, most learning environments do not contain multiple formats of learning materials, given that they are not designed with learners with disabilities in mind. Thus, the approach that will be discussed in section 4.3 will involve considering the needs of those with disabilities, in order to ensure that the learning environment is both accessible and usable (Nganji and Nggada, 2011). Even when the material is found in the learning environment, it must be correctly represented. Ontologies can facilitate the annotation of learning materials and hence their retrieval. To correctly match learners with suitable content, Vargas-Vera and Lytras (2008) suggest ontological interest-profiling. This thesis will make use of ontologies to represent knowledge about the learner, including their disabilities and their learning goals.

The following section will present a disability-aware approach to designing learning environments in order to ensure that they meet the needs of the learner. Chapter 2 presented various disabilities and how they affect the learner, which provides some background to understanding the need to develop disability-aware systems. By thinking about learners with disabilities and designing to meet their needs, this approach responds to the user sensitive inclusive design approach (Newell and Gregor, 2000a, Newell et al., 2010, Newell et al., 2011) which is a more realistic form of the user centred design approach.

4.3 An Ontology-Driven Disability-Aware Approach

In Chapter 2, various disabilities and how they affect the learner were discussed, including assistive technologies that could be employed for individuals with those disabilities. This was considered because such knowledge is important when designing any learning environment for students with disabilities. Learners with disabilities should be matched with the correct format of learning materials if they would be able to access the materials. Power et al. (2010) suggested that learning materials be presented to students with disabilities in adapted formats that are suitable for them. In Chapter 3, various approaches to designing learning environments for students with disabilities were also considered. Most notable among such approaches is the paradigm of user sensitive inclusive design where the authors argue that "inclusive" rather than "universal" be used since it is more achievable than "universal design" or "design for all". They also argue that "sensitive" should replace "centred" because it is difficult to design a product that can be accessible to all potential users (Newell et al., 2011). This approach is closely related to the ontology-driven and disability-aware approach that is considered in this thesis. This involves anticipating that people with disabilities will use the product and not only engaging with them at the end for testing purposes, but also involving them in the process. Thus, a disability-aware approach considers the needs of the learner throughout all stages of development and involves them in the process. This approach does not focus on the needs of a particular group of students with a specific disability but seeks to address the needs of all students with disabilities through adaptation to individual situations.

A number of learning environments have been designed considering the needs of the learner with disabilities. The AGENT-DYSL approach by Tzouveli et al. (2008b) focused on the needs of learners with dyslexia. As already discussed in Chapter 2, the

problem is that it only focuses on a specific disability. It was also noted in Chapter 2 that a learner might present with more than one disability type. So, to design a learning environment that responds to the needs of one of those disabilities and ignore the other disability will neither be user sensitive nor inclusive. The Moodle^{Acc+} environment (Laabidi et al., 2014) allows learning content to be adapted to the needs of the learner, thus being user sensitive. Nevertheless, it is not fully inclusive as it does not consider adaptation for learners with multiple disabilities. The approach used in this thesis allows the learning environment to analyse the needs of the learner and to adapt to such needs.

4.4 The ONTODAPS Model

One of the challenges facing existing web-based educational systems (WBES) is that of personalisation and adaptation to the needs of users (Dicheva, 2008) especially when these users present with various disabilities (Nganji et al., 2013b). The ontology-driven disability-aware model presented in this section is a result of research from literature which suggests the importance of web ontologies in personalising learning and which has been successfully employed to accomplish this and the need for inclusive design such as the user sensitive inclusive design paradigm (Newell and Gregor, 2000a). The increasing use of web ontologies as standards for describing learning materials as presented in Chapter 3 is testament to the usefulness of ontologies in the domain of e-learning. Also as discussed in Chapter 3, inclusive design approaches will ensure that the final product meets the needs of all learners. However, to accomplish this, this thesis adopts a disability-aware approach which considers the needs of all learners throughout the stages of development and additionally contains a mechanism for adapting to the needs of individual learners in order to ensure individual learning experiences. This is important given that each individual may have a different experience of a particular disability from another individual with the same disability and their preferences may be

different. Thus, it is important to capture such preferences through modelling the learner's preferences via their profile using semantic technologies and giving them the ability to manipulate the information stored in the ontology. In this research, students with disabilities as well as experts at the Disability Services at the University of Hull were consulted in order to understand the challenges that these students face. Also, the students were involved in an initial evaluation of the ONTODAPS system that will be described later on in this chapter and their opinions helped in improving the system.

To respond to the needs of individual learners, semantic web technologies such as ontologies can be used to build adaptive systems as described by Henze et al. (2004). Ontologies can be used to represent knowledge, enabling inferences to be made and can thus be very useful in the retrieval of learning materials from learning environments. Dicheva (2008) notes that the semantic web "aids learners in locating, accessing, querying, processing, and assessing learning resources across a distributed heterogeneous network". In order to present learners with the correct learning materials that are suitable for their needs, the ontology can be used to model the user and the learning materials thus serving as a link between the two (Monachesi et al., 2008). In the Personal Reader (Dolog et al., 2004a), learning support is achieved through the adaptation service sharing meta-information about courses, learning resources, and about learners. Devedzic (2004) suggests that using semantic web technologies, intelligent pedagogical agents can be used in locating educational material and also providing personalisation. The model in this thesis also makes use of ontologies to represent knowledge about courses, learning materials and the learners, thus facilitating matching the suitable learning materials to specific individuals. Individual components which are synonymous to agents work together to find specific learning materials for the learner based on specific needs thus acting as personalisation agents.

By being disability-aware, the learning environment is designed to be inclusive of all learners. Thus, learning materials can be presented in multiple formats, responding to the needs of all learners. The various formats include: text, audio, video, Braille, etc. with audio and video containing captions to be inclusive of those with hearing impairments while also being very useful to those with dyslexia. Designing for various disabilities will be beneficial to all learners.

The ontology-driven and disability-aware model presented in Figure 2 utilises the power of web ontologies to model information regarding various courses, learning materials and the learners as suggested by Dolog et al. (2004a) in the Personal Reader and employing various intelligent agents (Devedzic, 2004) to support the learner in locating and presenting specific learning materials. Unlike in traditional pedagogical agents that are animated, the agents here are not animated agents but are intelligent agents composed of various ontologies and algorithms to ensure adaptation and personalisation in order to deliver to the real needs of the learner. To correctly deliver to such needs, the agents in this model are disability-aware. Although being autonomous agents, they also collaborate with others within the learning environment to respond to the needs of the learner (Nganji and Brayshaw, 2011, Johnson et al., 2000). Seok et al. (2010) presented a learning model where various concepts such as the object of learning, subject of learning and mediator of learning are utilised. Inspired by that model, in the ontology-driven disability-aware model, the learning material is conceptualised as an object, the learner who might or might not have disabilities as a learning subject and the personalisation agents as mediator of instruction with the entire model driven by various ontologies as shown in Figure 2.

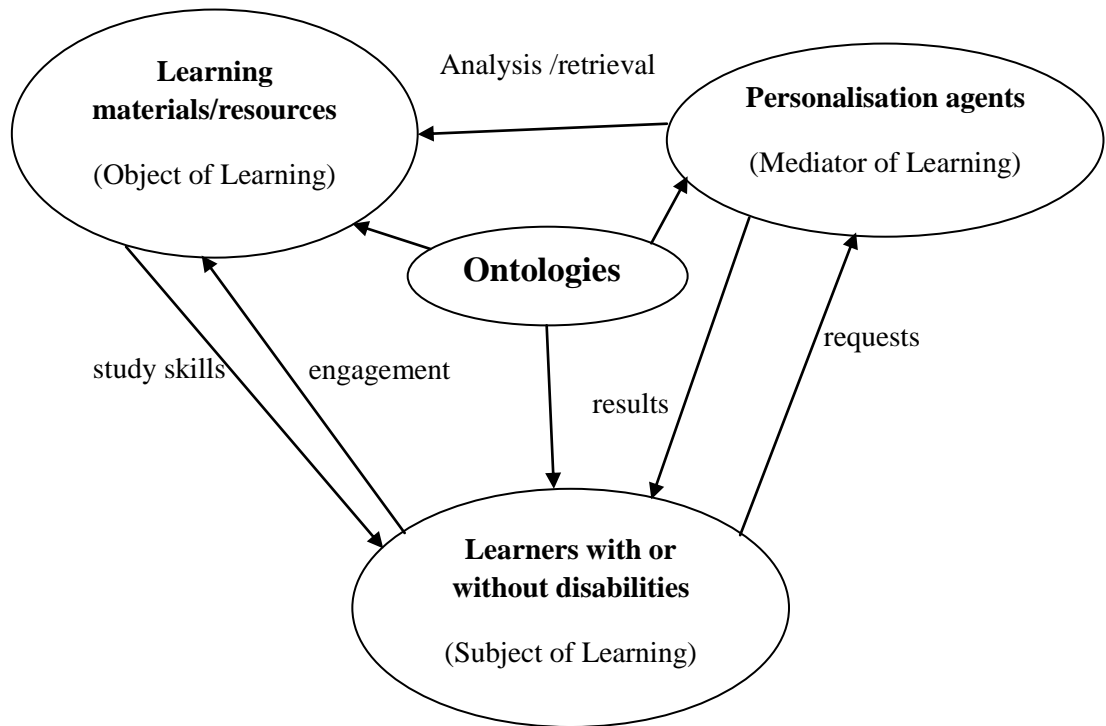


Figure 2. The ONTODAPS Model [Adapted from Seok et al. (2010)]

The ONTODAPS model is divided into four main areas thus:

4.4.1 Learning materials/resources (Object of Learning)

The learning resources are an important component of the model because they are the object of learning which enable the learner to achieve certain learning tasks. The modelling of learning resources will be explained in greater detail in Chapter 5 of this thesis. The literature review in Chapter 2 showed that students with disabilities face numerous challenges with existing learning environments (Fichten et al., 2009b, Asuncion et al., 2010) particularly relating to access to learning content and that e-learning could be advantageous in presenting information to students with disabilities in adaptable formats that are suitable for their needs (Power et al., 2010). In a vast repository of learning materials, there could be those that are not of suitable formats to the needs of the learner presenting with specific disabilities. Thus, in this case, it could be challenging for a learner with disability to retrieve the materials that are both relevant

to the course, are of the correct format for their disability type and compatible with their assistive technology. Knowledge on designing learning materials accessibly thus becomes important when disability is involved. The presence of learning materials in video and audio formats without captions for instance would be of very little or no use for a learner with hearing impairment. On the other hand, inclusion of multiple formats of learning materials within the learning environment will ensure inclusiveness as a wider group of learners will be able to access such materials as opposed to focusing on the needs of a specific group of learners. Within the model, the learning materials are what have been ontologically described and are analysed and retrieved by personalisation agents for presentation to the learner. When the learning materials are modelled with relevant semantic web technologies, the learners (subjects) can readily engage with the materials in the formats appropriate for them and compatible with any assistive technologies and can use their study skills to obtain relevant information that would be beneficial to their studies.

4.4.2 Learners With or Without Disabilities (Subject of Learning)

In the universal design and inclusive design approaches, the learner is the main focus as the designer seeks to meet their needs. Newell et al. (2011) suggest that designers develop an empathy with their user groups in order to develop products that are not only "accessible" but usable to them. By engaging learners with disabilities throughout the design, the designer will develop a disability-aware approach (Nganji and Nggada, 2011) which is empathetic. A key component of the model in this thesis is disability awareness where the needs of the learner with disability are modelled using semantic web technologies such as ontologies in order to facilitate querying the information. Thus, personalisation agents in the model will be able to interact easily with the information about the user in order to present them with the correct information they

request. User sensitivity has also been employed in other learning systems for learners with disabilities such as the AGENT-DYSL system which "employs age appropriate and dyslexia-sensitive user interfaces" (Tzouveli et al., 2008b) and an e-learning system for students with visual impairments (Drigas et al., 2006) which employs the "design for all" and "universal accessibility" approach, just to name a few. Nevertheless, this model is unique in that it provides for the needs of learners with multiple disabilities to be considered in order to respond to their learning needs in addition to their special needs. Thus, disability awareness is a key component when designing systems for people with disabilities, if the systems would respond to their needs. Greater details on how learners are modelled using semantic web technologies are presented in the Case Studies in Chapter 5 of this thesis.

4.4.3 Personalisation Agents (Mediator of Learning)

As discussed in Section 4.4, according to Devedzic (2004), pedagogical agents play a vital role in intelligent web-based educational systems by "providing the necessary infrastructure for knowledge and information flow between the clients and servers" and thereby supporting human learning by interacting with students/learners and authors/teachers and by collaborating with other similar agents in the context of interactive learning environments (Johnson et al., 2000). The personalisation agents used within this model play a similar role unless that they are not presented as animated persons but are similar to a community of agents (Nganji and Brayshaw, 2011) playing the part of a tutor in that they fetch relevant information and present to the learner based on their needs. To respond to the needs of learners with multiple disabilities, the algorithms of the personalisation agents play a vital role as demonstrated in Chapter 5 of this thesis.

4.4.4 Ontologies

The importance of ontologies in e-learning has been well documented. Ontologies help the organisation of learning materials into customised learning courses in order to deliver to the user based on their profile and business needs (Stojanovic et al., 2001). Sampson et al. (2004) expect the semantic web to greatly influence e-learning systems and applications. Lytras et al. (2003a) suggest that ontologies can be used to represent knowledge in a specific domain. Monachesi et al. (2008) suggest that "ontologies can enhance the management, distribution and retrieval of learning material within a Learning Management System". Stojanovic et al. (2001) note that in the e-learning domain, learning materials can be semantically annotated and based on the learner's preferences can find and combine useful learning materials very easily. The model in this thesis makes use of ontologies as the core component to drive retrieval of useful learning materials as well as adaptation and personalisation. The ADOOLES ontology used in this thesis is described in Section 4.6 while Chapter 5 shows how learning resources are modelled with ontologies to facilitate retrieval.

The following section will discuss the design of the ONTODAPS model through a presentation of its architecture and explanation of how various agents/components function to present the learner with the desired learning materials.

4.5 Architecture of ONTODAPS

Before presenting the architecture of ONTODAPS, some architectures of e-learning systems which help in personalisation or adaptation will be considered.

4.5.1 E-Learning System Architectures

One of the earliest adaptation models, AHAM (De Bra et al., 1999): Adaptive Hypermedia Application Model was an extension of the Dexter model. In this model,

the topmost layer, the run-time layer represents the user interface on top of a presentation specifications layer and a storage layer containing three models: an adaptation model which combines elements from a domain model and user model to describe an event, a domain model which contains a conceptual representation of the application domain and a user model containing conceptual representations of all aspects of the user relevant for the adaptive hypermedia application. Whilst the user model represents aspects of the user, it does not specifically deal with users with disability, and does not show how such model can be employed to personalise or adapt services for people with disabilities.

The FOHM (Fundamental Open Hypermedia Model) model (Millard et al., 2000) defines a common data model and set of related operations that are applicable for the three hypertext domains of navigational hypertext, spatial hypertext and taxonomical hypertext. However, for this model to adapt to the needs of the user, it requires a standalone engine called Auld Linky, which manages the XML "linkbase" of association structures expressed in FOHM .

As discussed earlier, Lytras et al. (2003b) suggest that "a Java platform which follows an XML communication standard, through web services, in order to give an integration fulfilment between learners and learning repositories, is an ideal solution for designing a system which can be adopted easily". With the introduction of the Semantic Web, newer architectures and systems such as the Personal Reader (Henze and Herrlich, 2004) make use of Semantic Web technologies for personalisation. In this framework, different web services cooperate with each other by exchanging RDF documents to form a Personal Reader instance. One of the key advantages with this framework is that it enables users to select services which provides extended functionality such as personalisation services, combining them into a Personal Reader instance. This framework is however

not specific for people with disabilities and does not describe how to deal with special needs.

Chapter 2 shows that there is a gap in using ontologies to personalise services to people with disabilities. Such needs are currently being met albeit to a less sufficient extent with existing models as discussed in Chapter 2. Such models are not robust enough to handle multiple cases of disability, which necessitates an adaptation of existing architectures by providing the missing components needed for such personalisation or the development of newer models. The architectural model presented in this chapter, although emphasising the needs of people with disabilities, can be used for people without disabilities, thus being inclusive. Additionally, as will be seen in Chapter 5, it provides a means of delivering effective personalisation for cases of multiple disabilities.

4.5.2 Description of the ONTODAPS Architectural Model

The system architecture defined here is also discussed in Nganji et al. (2011) and Nganji and Brayshaw (2011). The system architecture comprises four main agents which work together to provide the student with personalised e-learning resources based on their learning needs and disability type as show in Figure 3. As discussed in Section 4.4.3, there are personalisation agents which consist of a community of agents and in the architecture are presented as individual agents or components which work together to provide the learner with the information that is requested. The various agents will be discussed, including their application in the following sections. However, for more information on how the agents work, please refer to the case studies in Chapter 5.

4.5.2.1 Information Translation and Presentation Agent

This agent enables students with disabilities to obtain content suitable for their specific needs. Initially, a student interacts with the semantic web enabled system through the

visual interface, which first presents them with the option of choosing specific learning goals as well as editing their profile. When the agency identifies the student as one with special needs through the information which is stored in their user profile, the system retrieves the learning resources that are specific and suitable for their disability and in line with their individual learning goals and other preferences. This comes about when the student views the available courses and selects the ones they wish to study and prompts the system to personalise those courses. Personalisation here presents the courses in either of three formats (video, audio, text) or a combination of those formats although other formats such as digital Braille could also be included. The student can then select an appropriate format for a specific learning resource and click to access the learning resource.

This presentation in specific formats is facilitated by the translation module which translates and presents the resources to the student in an appropriate format. A more detailed functioning of this personalisation mechanism will be presented in chapter 5 when some case studies will be considered.

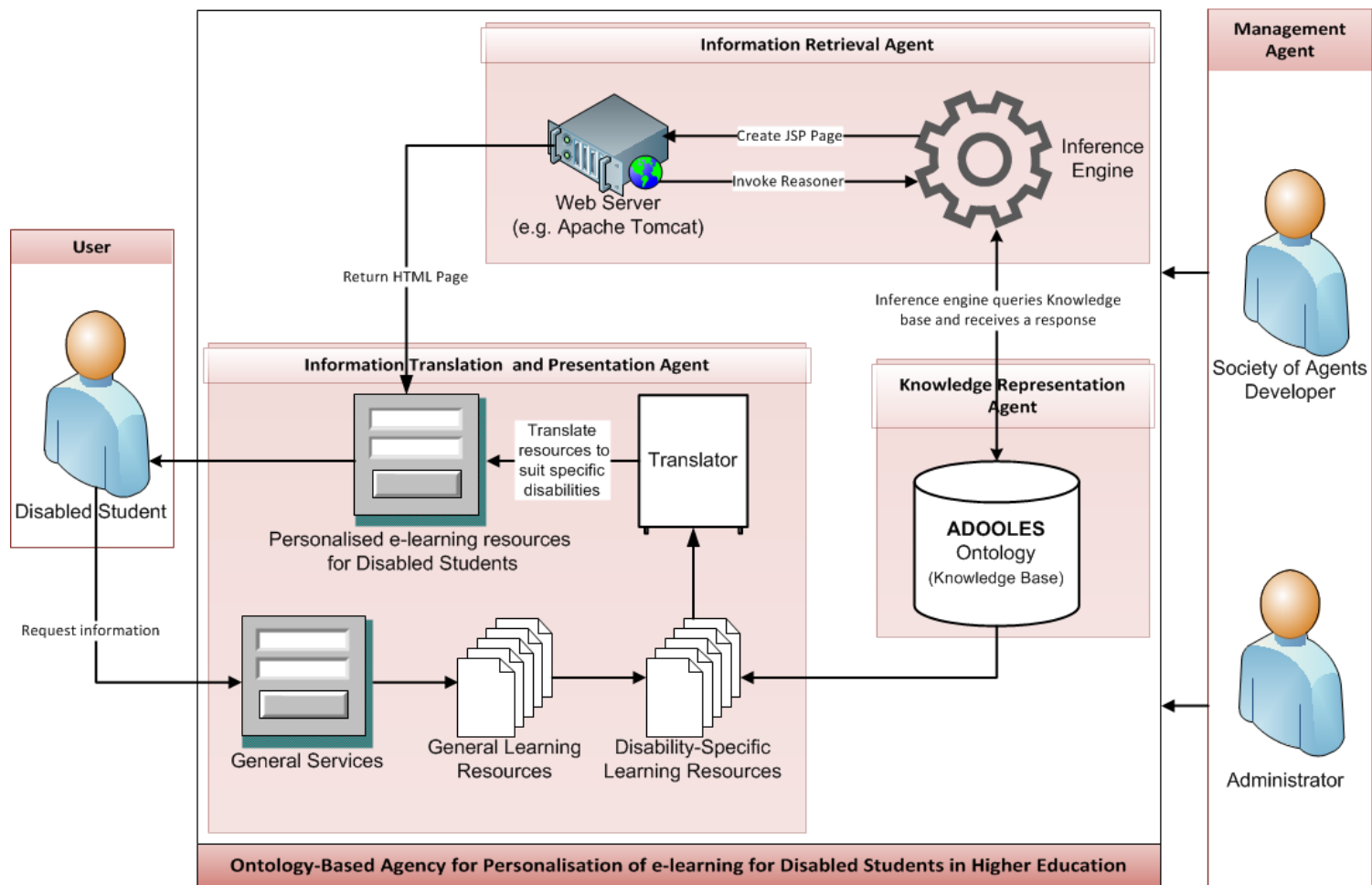


Figure 3. Architecture of Ontology-Driven Disability-Aware Personalised E-Learning System (ONTODAPS)

4.5.2.2 Knowledge Representation Agent

Knowledge representation improves information retrieval and ease of representation (Martin and Eklund, 1999). This agent represents domain knowledge in a format that could be easily understood and interpreted by the e-learning system. Knowledge about the user and the courses are stored in an ontology as recommended by Monachesi et al. (2008).

This agent has a disability ontology specified in OWL (Web Ontology Language) and can be stored in XML format. Defining an ontology as a "specification of a conceptualisation" in e-learning involves a holistic approach to issues that affect performance and revealing of causal relationships (Lytras et al., 2003b). The ontology herein contains various concepts such as Ability, Disability, Assistive Mechanisms, Person, Course and Services, which all form the main classes. The ontology is known as Abilities and Disabilities Ontology for Online LEarning and Services (ADOOLES) and incorporates some concepts, classes and properties contained in the ADOLENA ontology (Keet et al., 2008). This ontology will be fully discussed in the later parts of this chapter, including how it differs from the ADOLENA ontology.

4.5.2.3 Information Retrieval Agent

This agent is one of the key agents of the web-based system which interacts with the knowledge representation agent to collect information on the learning resources that are being requested, transmitting it to the information translation and presentation agent. It has an inbuilt inference engine which queries the ontology, interacting with the inference engine to present the information to the user. This agent's functioning will be demonstrated in Chapter 5 when some case studies are considered.

4.5.2.4 Management Agent

This agent has a visual interface which enables administrators such as lecturers, agency administrators and developers to manage the student's profile. It enables the

administrator to add, edit or delete users and their details, as well as course information. Through this interface, information stored in the ontology can be manipulated.

4.5.2.5 The Learner/User

The learner in ONTODAPS represents an individual with or without disabilities who interacts with the system to carry out specific tasks that will help them in their studies. Based on the ONTODAPS model presented in section 4.4, the learner is the subject of learning. Their profile is modelled using ontologies and stored in the ADOOLES ontology from whence they can readily manipulate the information from the visual interface in order to retrieve specific learning materials. The ontology thus acts as a link between the learner and the learning materials (Monachesi et al., 2008) as earlier mentioned in Section 4.4. Chapter 2 revealed that learner profiles are commonly used to provide personalisation in e-learning. This is done by storing vital information about the user in their profile.

As revealed from literature in Chapter 2, most e-learning systems do not consider the needs of learners with multiple disabilities and thus cannot provide personalisation or adaptation to meet the needs of such individuals. As discussed in Chapter 3, Devedzic (2004) suggests that educational services, user group constraints and preferences be marked up semantically. This facilitates search, retrieval and presentation of learning materials to the learner. Lytras et al (2003b) also corroborate that this semantic approach will lead to an intelligent system, provide personal annotation of learning materials and enable reuse of learning materials.

In the ONTODAPS model, information about the learner's disabilities are modelled using ontologies, allowing for such information to be readily manipulated. A key consideration is that the learner's disabilities are modelled and the learner is given the ability to manipulate the information that is stored in the ontology, by being able to

update that information whenever they need. This is very important because the learner could present with different disabilities which may either get worse or are improved and thus they can be able to change the severity of the disability and can add or remove other disabilities as required. The system thus adjusts to the needs of the learner.

Detailed information on how the ONTODAPS model works for learners with different types of disabilities are presented in the Case Studies in Chapter 5.

4.6 The ADOOLES Ontology

The ADOOLES (Abilities and Disabilities Ontology for Online LEarning and Services) ontology which is an extension of the ADOLENA ontology (Keet et al., 2008) constitutes the knowledge representation agent in the ONTODAPS model. The word ontology originates from Philosophy and refers to the subject of being or existence. In Computer Science however, Gruber (2009) defines ontology as “a specification of a conceptualisation”. Also noted is the fact that:

“ontologies are used for integrating heterogeneous databases, enabling interoperability among disparate systems, and specifying interfaces to independent, knowledge-based services”. Gruber (2009).

Ontologies also play a vital role in personalising information for both people with disabilities and people without disabilities and can be employed in managing vast amounts of information. ADOOLES was developed to personalise online learning (e-learning) and services for students with disabilities and students without disabilities in education.

There are several methodologies used in developing ontologies, which - according to Fernandez-Lopez and Gomez-Perez (2002) - include:

Cyc: This methodology (Lenat and Guha, 1990) has three phases, the first phase involving manual coding of explicit and implicit knowledge without using natural language, the second phase involving coding knowledge in the knowledgebase using tools and a third phase mainly involving the use of tools.

Uschold and King: In this methodology (Uschold and King, 1995), to build an ontology, one needs to identify the purpose of the ontology, build the ontology, evaluate the ontology (making a technical judgement) and document how the ontology was built.

Grüninger and Fox: This is based on the experience from developing the TOVE (TOronto Virtual Enterprise) project ontology which focuses on business processes and activities modelling. This methodology (Grüninger and Fox, 1995) assumes that ontology development is motivated by scenarios arising in the application. There are two steps in developing an ontology using this methodology. First, the motivating scenarios are captured; then there is a formulation of informal competency questions based on the above scenarios.

KACTUS approach: According to Fernandez-Lopez and Gomez-Perez (2002), citing Bernaras et al. (1998), this approach involves refining the ontology that is used for building an application each time an application is built. Thus the steps to building an application include specifying the application, preliminary design based on relevant top-level ontological categories and ontology refinement and structuring.

The ADOOLES ontology has been designed to incorporate concepts in education related to various disabilities and can be used to integrate learning services and disability-related information systems. The ontology uses concepts such as ability, assistive mechanism, course, disability, person and services which constitute its classes. This ontology contains relevant information for students with disabilities as well as students without disabilities, although the emphasis here is on students with disabilities.

This research adopts some of the concepts used in the HESA (Higher Education Statistics Agency) statistics for higher education relating to disabilities such as the terms used in describing the disabilities as well as their grouping, together with some concepts from the ADOLENA (Abilities and Disabilities OntoLogy for ENhancing Accessibility) ontology (Figure 4) and the WHO International Classification of Functioning, Disability and Health (ICF). In discussing the various classes of the ontology, those that were adopted from ADOLENA will be identified. The ICF framework is made up of two parts, which include Functioning and Disability and Contextual Factors. Of interest in the ADOOLES ontology is the Functioning and Disability part, which includes Activity and Participation. Activity and Participation describes an individual's functional status and includes communication, mobility, learning etc. Communication is part of the Ability class, while Mobility is used to describe the disabilities that affect mobility such as mobility difficulty (Figure 7). ADOOLES uses the range of disabilities described in the HESA statistics for disability such as specific learning difficulty, blind/partially sighted, deaf/hearing impairment, wheelchair user/mobility difficulty, mental health difficulties, unseen disability and autistic spectrum disorder. Other classes such as *Course*, *Person* and *Services* are also introduced in the ontology, which are lacking in the ADOLENA ontology.

Considering the methodologies for developing ontologies that were discussed above, the development of the ADOOLES ontology closely follows the methodology used by Uschold and King (1995), where before building the ontology, the purpose of the ontology was first identified as an ontology that “will be used for personalising learning resources and services for all students, including those with multiple disabilities”. Then, an existing ontology, the ADOLENA ontology (Keet et al., 2008) was obtained and additional classes added to it during the ontology building phase, where key concepts in the domain of disability and learning were added based on data from the HESA

statistics (HESA, 2012) and from the needs of students with disabilities obtained during the requirements phase of the design where the students and disability experts were consulted and from the author's personal experience working with students with disabilities and knowing their needs. The relationships between the concepts were also identified. During this building phase, the knowledge was then represented using the Protégé tool. The development of the ontology was then documented.

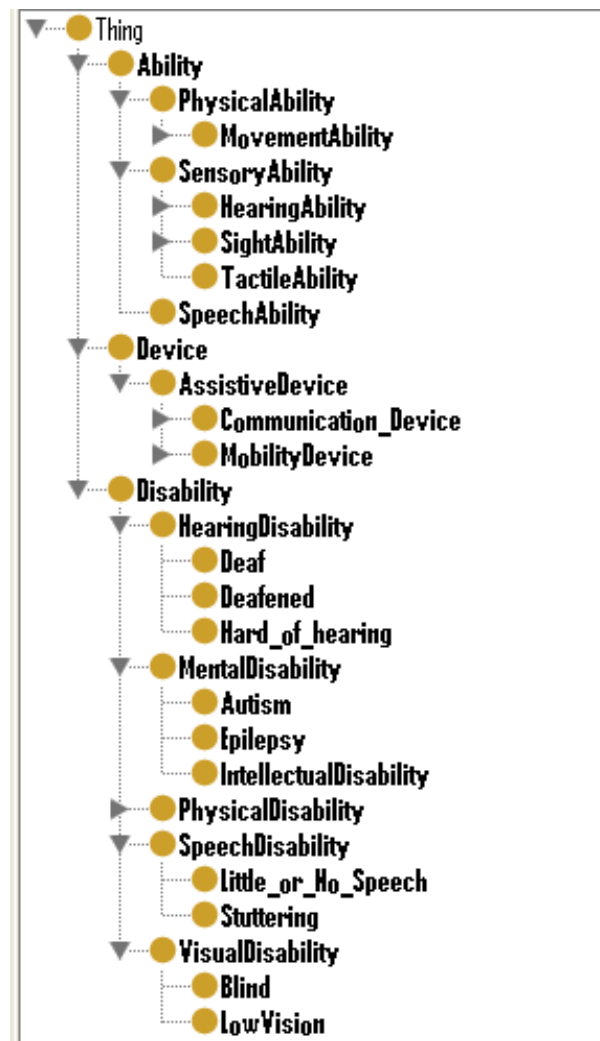


Figure 4. ADOLENA ontology class hierarchy

ADOLES was designed using Protégé 4.2, an open-source ontology development tool which has plugins that can be used to visualize the ontology. This visualisation gives a quick overview of the whole ontology and has been used in this work to facilitate

understanding of the structure of the ontology as represented in various figures within this chapter. For instance, some members of the *Course* class can be seen in Figure 16 (OntoGraf visualisation) while the *Disability* class is presented in Figure 18 (OWLviz visualisation). To understand ADOOLES, some sections of the ontology will be described, with examples. This will be presented in the RDF/XML notation.

As discussed above, before designing ADOOLES, the researcher considered the purpose of the ontology in order to decide on the concepts needed for the ontology. This was done after researching available reusable ontologies. The only comprehensive disability ontology closely related to this study and available online for access was the ADOLENA ontology (Keet et al., 2008) which was developed and used to improve the accessibility of the National Accessibility Portal (NAP) in South Africa. The ADOLENA ontology is "based on the semantics in the NAP database and also augmented with notions from foundational and related domain ontologies" and contains four principal concepts: *Ability*, *Disability*, *Device* and *Functionality* (Keet et al., 2008). Some concepts in ADOOLES such as the various abilities, disabilities and devices were reused from ADOLENA with a few additions where necessary to suit ONTODAPS development as discussed in Section 4.6.2. ADOLENA contains other concepts that were not relevant to this work and also lacked some concepts that were needed for this application. Also, some grouping of disabilities in the ADOLENA ontology differs from that used by HESA. For instance, epilepsy is grouped under Mental Disability in ADOLENA whereas it is generally considered as an unseen disability in the UK; hence it was classified as unseen in the ADOOLES ontology. This does not greatly change the ADOLENA ontology as the class was simply moved to a different category. Due to these and other disparities, the entire ontology could not be reused. Instead, ADOOLES incorporated a class known as *Services*, which contains various services that could be accessed by students with disabilities at the University and can be personalised for

them. The *Services* class was included because in an educational setting, students with disabilities would usually contact a disability service, which then recommends to them the various accommodations that would be helpful to them in their course. Thus an ontology which considers the services that are offered to students with disabilities in education needs to reflect this. A *Course* class which contains information about the course a student could access was also necessary as this research focuses on the education domain, and a *Person* class which contains information about the users (students and administrators) were added to the ADOLENA ontology to form the ADOOLES ontology.

4.6.1 The Ontology Header

ADOOLES ontology starts with some XML namespace declarations with the initial set enclosed in an opening `rdf:RDF` tag as seen in Figure 5.

```
<rdf:RDF xmlns="http://www.hull.ac.uk/php/323567/ontologies/adooles.owl#"
  xml:base="http://www.hull.ac.uk/php/323567/ontologies/adooles.owl"
  xmlns:adooles="http://www.hull.ac.uk/php/323567/ontologies/adooles.owl#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:owl="http://www.w3.org/2002/07/owl#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
```

Figure 5. The ADOOLES ontology header

Just like any other ontology, ADOOLES has a Unique Resource Identifier (URI) which in this ontology (Figure 5) is `http://www.hull.ac.uk/php/323567/ontologies/adooles.owl#`.

The namespace declarations identify the base URI for ADOOLES ontology with various vocabularies such as RDF (`xmlns:rdf`), RDFS (`xmlns:rdfs`) and OWL (`xmlns:owl`). The ontology also contains some assertions found under the `owl:Ontology` element as in Figure 6.

```

<owl:Ontology rdf:about="http://www.hull.ac.uk/php/323567/ontologies/adooles.owl">
  <owl:versionInfo>ADOOLES V2</owl:versionInfo>
  <rdfs:comment>This is an ontology to represent the disabilities encountered in
  Education. The ontology does not list all disabilities existing in education but focuses on
  some common ones amongst students. The aim is to use this ontology to personalise
  learning resources and services for students with and without disabilities. This ontology
  uses some of the relevant properties and concepts found in the ADOLINA ontology,
  but incorporates other concepts relevant to education as well as some other properties.
</rdfs:comment>
  <owl:priorVersion>ADOOLES V1</owl:priorVersion>
  <owl:versionIRI
rdf:resource="http://www.hull.ac.uk/php/323567/ontologies/adooles.owl"/>
</owl:Ontology>

```

Figure 6. ADOOLES version information

The owl:versionInfo assertion is a statement relating to the version of the ontology while the rdfs:comment contains comments about the ontology.

4.6.2 The Ontology Classes

ADOOLES ontology was designed using various concepts related to ability, assistive mechanism, course, disability, person and services; which all form the main classes of the ontology as represented in Figure 7.

This section will discuss the classes, including their subclasses and identify their source, whether they came from the ADOLINA ontology or were new classes added and the relevance of those classes.

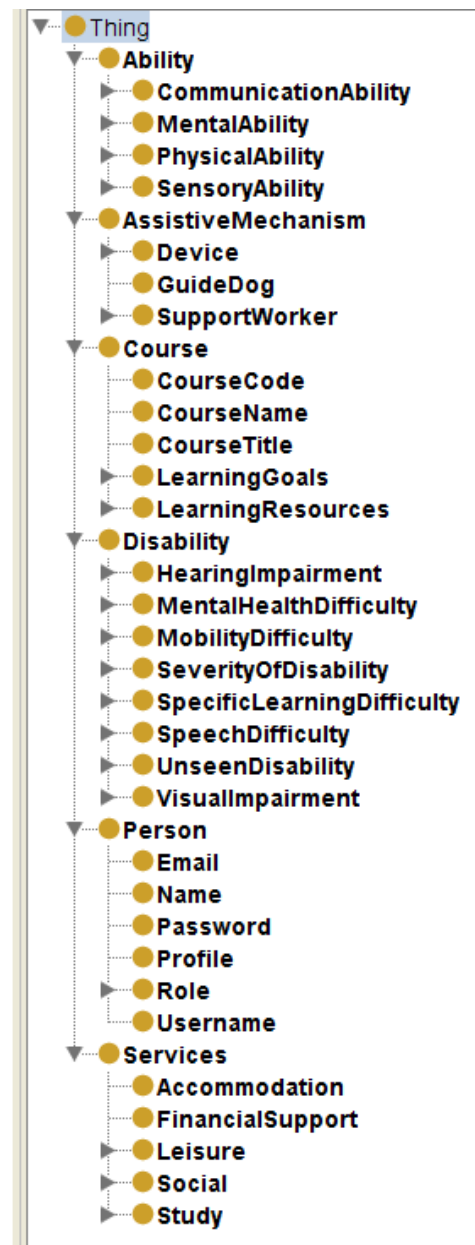


Figure 7. ADOOLES ontology class hierarchy

In Protégé, the owl class owl:Thing is a predefined class. Similarly, the class owl:Nothing is also predefined and empty. Some of the classes in the ADOOLES ontology are shown in the XML representation in Figure 8.

```

<owl:Class rdf:about= "#Ability">
  <rdfs:subClassOf rdf:resource= "#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource= "#isAssistedBy"/>
      <owl:someValuesFrom rdf:resource= "#AssistiveMechanism"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

```

Figure 8. An ADOOLES class

To display a subclass, the following notation in Figure 9 is used.

```

<owl:Class rdf:about= "#Superclass">
  <rdfs:subClassOf rdf:resource= "#Subclass" />
</owl:Class>

```

Figure 9. Representing a superclass in ADOOLES

Hence, *Anxiety* which is a subclass of *MentalHealthDifficulty* is represented in the ontology as shown in Figure 10.

```

<owl:Class rdf:about= "#Anxiety">
  <rdfs:subClassOf rdf:resource= "#MentalHealthDifficulty"/>
</owl:Class>

```

Figure 10. Representing Anxiety as a subclass of *MentalHealthDifficulty*

In the ADOOLES ontology, members of the same class share some common characteristics. Members of the *Disability* class for instance, are characterised by some impairment in their functions. For instance those with visual difficulties have visual impairment which could be total blindness or partial sight. As we go down the class, the relationship is further strengthened as siblings share greater similarities.

a) The Ability Class

This class was adopted from the *Ability* class of the ADOLENA ontology (Keet et al., 2008). It represents the various abilities of an individual which may be affected by an impairment in their functions, thus leading to a disability. This class is important in that

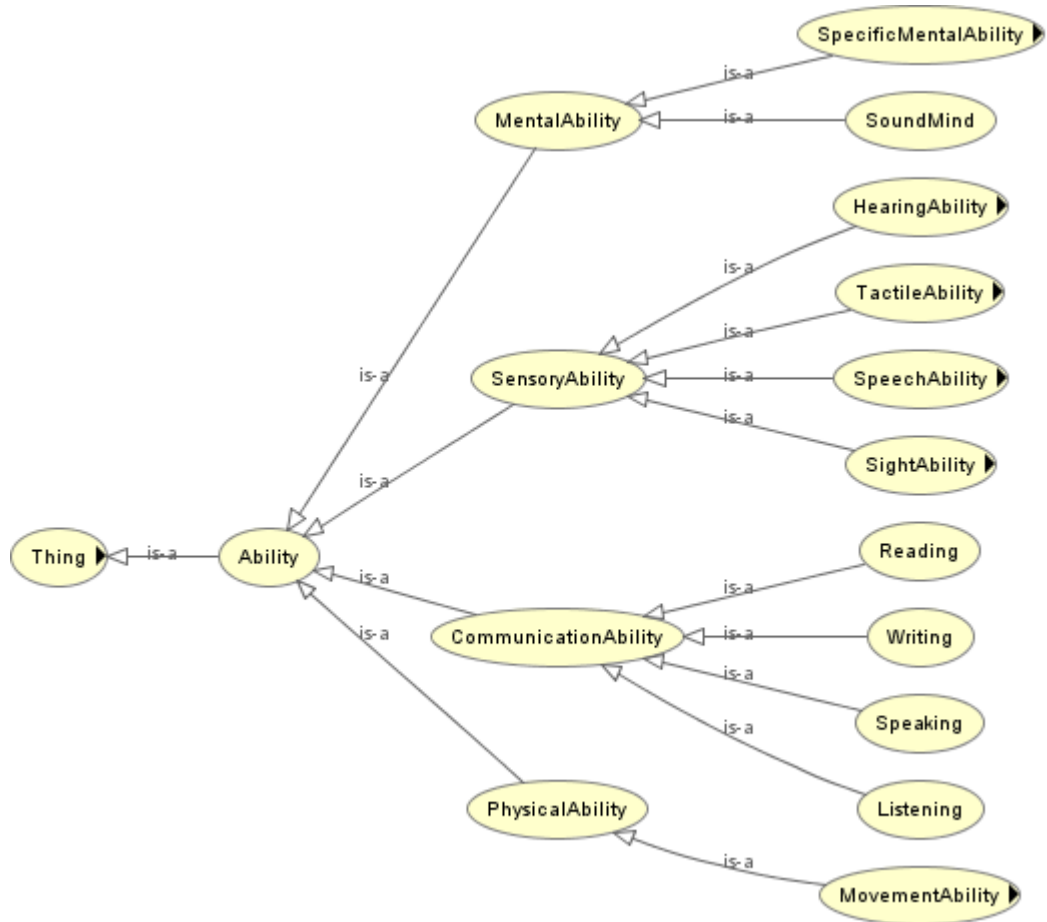
to use an assistive technology, an individual requires some ability. For instance, to use a screen reader, although an individual may be blind, they will depend on the sense of sound to receive information that may be in text format and is read out to them using a screen reader or text to speech; they thus require the ability to hear. The RDF/XML representation of the class *Ability* is found in Figure 11 and its graphical representation in Figure 12.

```
<owl:Class rdf:about= "#Ability">
  <rdfs:subClassOf rdf:resource= "#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource= "#isAssistedBy"/>
      <owl:someValuesFrom rdf:resource= "#AssistiveMechanism"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

Figure 11. RDF/XML representation of Class *Ability* including *isAssistedBy* property

Members of the *Ability* class in ADOOLES include *CommunicationAbility*, *MentalAbility*, *PhysicalAbility* and *SensoryAbility*. In ADOLENA, the members of the *Ability* class include *PhysicalAbility*, *SensoryAbility* and *SpeechAbility*. Thus *SpeechAbility* was renamed to *CommunicationAbility* while *MentalAbility* was added. The ability to communicate as represented by the *CommunicationAbility* includes *Listening*, *Reading*, *Speaking* and *Writing* which all form subclasses. These subclasses are new subclasses that were added to the ADOOLES ontology as it focuses on learning and listening, reading, speaking and writing are important aspects of learning.

MentalAbility on the other hand includes *SoundMind* and *SpecificMentalAbility* as subclasses. *SpecificMentalAbility* is further subdivided into *Calculation*, *Language*, *Learning* and *Memory*. These are all related to learning and the ontology needed to capture these.

Figure 12. Graphical representation of the *Ability* class

PhysicalAbility which was adopted from the ADOLENA ontology contains the subclass *MovementAbility* which contains *LimbMobility* and *Reach* as subclasses. In the ADOOLES ontology, *Reach* was replaced by *Direction*. When moving as in the case of an individual who is blind, direction is important. They need to be able to move in the correct direction. *LimbMobility* refers to *UpperLimbMobility* and *LowerLimbMobility* which were all adopted from ADOLENA. This mobility is important as individuals with impairment might not be able to access information well, if e-learning systems are not designed to consider their needs. An individual with upper limb mobility difficulty who suffers from tremors may find it very difficult to use a mouse as input device; this can be compounded by using very small icons or targets on an interface. For an individual with lower limb mobility difficulty such as a wheelchair user, the university physical

environment will need to be altered to grant access to a lecture hall. Ramps and lifts will be needed where these are not available, else, the student will be left out.

In the ADOOLES ontology, *SensoryAbility* includes *HearingAbility*, *SightAbility*, *SpeechAbility* and *TactileAbility*; whereas in the ADOLENA ontology, *SensoryAbility* includes the subclasses *HearingAbility*, *SightAbility* and *TactileAbility*. Thus, *SpeechAbility* which was a subclass of *Ability* in ADOLENA was moved to a subclass of *SensoryAbility*. Thus, ADOOLES considered the sensory abilities in terms of the senses. All of these sensory abilities could be complete or partial. An individual may be able to hear completely or partially.

The *Ability* class could thus help to determine what assistive mechanism is needed for an individual who has certain abilities and disabilities.

b) The AssistiveMechanism Class

The *AssistiveMechanism* class (Figure 13 and Figure 14) of ADOOLES was taken from the ADOLENA ontology (Keet et al., 2008) *Device* class and renamed as assistive mechanism in order to better reflect the concept of support that is usually offered to students with disabilities by a disability service in an educational institution. The support can be in the form of technology or human support, hence, it will not be wise to classify human support workers as devices. The class thus contains the assistive technology devices which are part of the *Device* class of ADOLENA but additionally includes *GuideDog* and *SupportWorker*. The *Device* class contains *CommunicationDevice*, *LearningDevice* and *MobilityDevice*. The ADOLENA ontology does not contain the *LearningDevice* class. Since ADOOLES deals with an educational context, it was appropriate to include this class in order to name the devices that could be useful in students' learning.

```

<owl:Class rdf:about="#AssistiveMechanism">
  <rdfs:subClassOf rdf:resource="#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#alleviates"/>
      <owl:someValuesFrom rdf:resource="#Disability"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

```

Figure 13. RDF/XML representation of the *AssistiveMechanism* class

CommunicationDevice includes *ListeningDevice* which also contains *HearingAid* (in the ADOLINA ontology, there is *TelephoneAid* instead), *ReadingDevice* which contains *BrailleReadingDevice*, *ScreenMagnifier* and *ScreenReader*; *SpeechDevice* and *WritingDevice* which contains *BrailleWritingDevice* and *InputDevice*. In ADOLINA, *ReadingDevice* contains the subclasses *TactileReading* (subclasses being *BrailleAlarmClock*, *BraillePillOrganiser*, *BrailleWatch*) and *TalkingReading* (with subclass *Talking_Thermometer*). The *InputDevice* which is unique to ADOOLES constitutes *Joystick*, *Keyboard*, *Mouse*, *Scanner* and *TextToSpeech*. The communication devices enable an individual to communicate in various ways and help compensate for a specific disability.

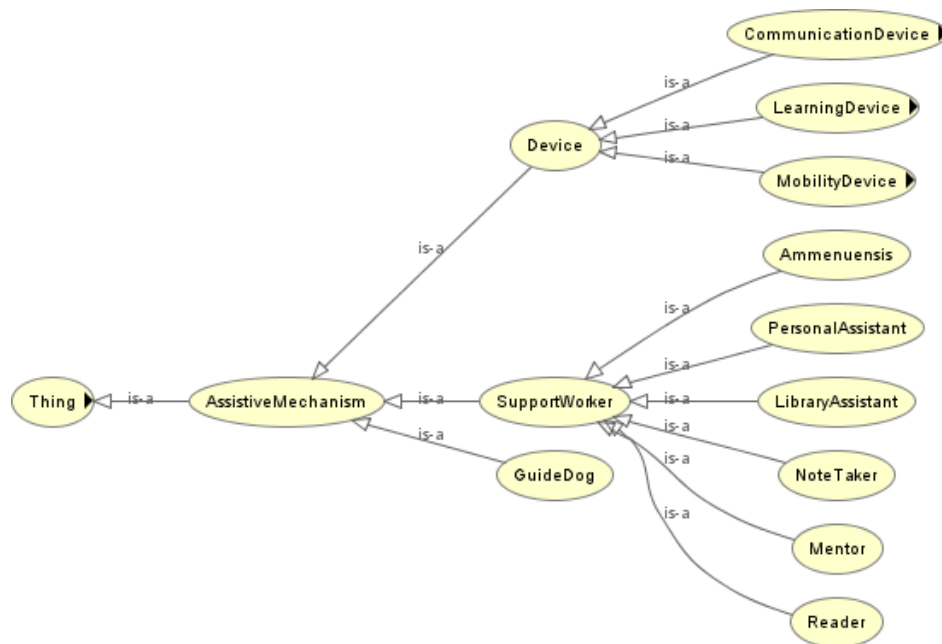


Figure 14. The Assistive Mechanism Class

LearningDevice which is a new class in ADOOLES contains *Computer*, *Internet*, *SoundRecorder*, *VideoRecorder* and *Web*. These are all devices or assistive technologies that can enhance learning for a student with disability. The ontology could be extended to include other learning devices.

MobilityDevice in ADOOLES which was adopted from ADOLENA only contains *Wheelchair* but the ontology could be extended to include other mobility devices as required. In ADOLENA, the *WheelChair* class is subdivided into *Manual_WheelChair* and *Motorised_WheelChair* which all have subclasses. As the National Accessibility Portal from which ADOLENA was derived deals with recommending specific assistive technologies, it was not necessary to be very specific in terms of the wheelchair in the case of ADOOLES as the type of wheelchair does not have an effect on the individual's learning. It was thus simply defined as wheelchair.

SupportWorker, an assistive mechanism that is unique to ADOOLES contains the subclasses *Amanuensis*, *LibraryAssistant*, *Mentor*, *NoteTaker*, *PersonalAssistant* and *Reader*. These are individuals who are normally recruited by the university probably through the Student Support or Disability Services to support students with disabilities in their learning. An intelligent e-learning system will be able to assess the needs of a student with disability and recommend such services to the student.

c) The Course Class

The *Course* class (Figure 15 and Figure 16) is found in the ADOOLES ontology but not in the ADOLENA ontology, as the ADOOLES ontology focuses on learning. The class was needed in order to capture information on the learning needs of a learner. This class contains information that can be used to store courses or modules which a student studies and consists of *CourseCode*, *CourseName*, *CourseTitle*, *LearningGoals* and *LearningResources* which are derived from how a learning system would model

courses. An e-learning system could utilise this information to facilitate search, retrieval and accessing of courses.

```

<owl:Class rdf:about="#Course">
  <rdfs:subClassOf rdf:resource="#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasGoal"/>
      <owl:someValuesFrom rdf:resource="#LearningGoals"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

```

Figure 15. RDF/XML representation of the *Course* class

LearningGoals contain other subclasses such as *LearningGoalCode* and *LearningGoalTitle*. *LearningResources* on the other hand contains *LearningResourceFormat* which represents the various formats in which the learning resource could be stored and recommended to a student based on their disability needs. Members of the *LearningResourceFormat* class include *Audio*, *Braille*, *Text* and *Video* and could be extended to include other formats. These formats are important as they can determine if a student with disability will be able to access a learning resource or not. If a student with severe hearing impairment (deafness) is recommended a resource in audio format and the audio does not have subtitles, then they will not be able to access the information. Thus, an e-learning system needs to present information in multiple formats and in a way that is disability-aware, taking the individual's disability into consideration and presenting them with information in an appropriate format. It is vital for such systems to also consider how multiple disabilities will be handled.

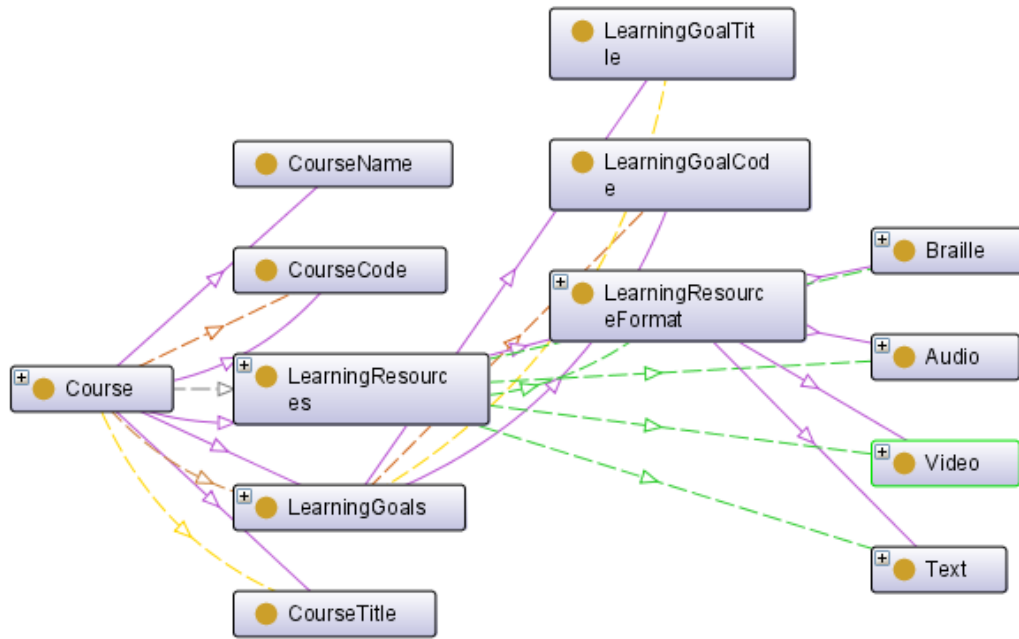


Figure 16. ADOOLES Course class visualised with OntoGraf

d) The Disability Class

Class *Disability* (Figure 17 and Figure 18) in ADOOLES is an abstract representation of the disabilities an individual could have which are encountered in education. This class was obtained from the ADOLENA ontology (Keet et al., 2008) but the classification of the disabilities were based on the classification used by HESA in their yearly statistics on disability in education. The various disabilities are modelled in ADOOLES as individuals. Although this class contains the main disabilities encountered in education based on HESA, it also lists some of the disabilities that have not specifically been mentioned in the HESA statistics. HESA acknowledges the fact that some disabilities might exist in education but are not mentioned by them. They use the code 09 to represent statistics for such disabilities.

The *Disability* class in ADOLENA contains the subclasses *HearingDisability*, *MentalDisability*, *PhysicalDisability*, *SpeechDisability* and *VisualDisability*. In

ADOOLES, the classes have been renamed to use the terms found in HESA statistics and other classes have been added to them.

```
<owl:Class rdf:about="#Disability">
  <rdfs:subClassOf rdf:resource="#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#isAlleviatedBy"/>
      <owl:someValuesFrom rdf:resource="#AssistiveMechanism"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

Figure 17. RDF/XML representation of a fragment of the *Disability* class

The main subclasses of class *Disability* in ADOOLES are *HearingImpairment*, *MentalHealthDifficulty*, *MobilityDifficulty*, *SpecificLearningDifficulty*, *SpeechDifficulty*, *UnseenDisability* and *VisualImpairment*. The *HearingImpairment* class contains *Deaf* and *HearingImpaired* as subclasses whereas in the ADOLENA ontology, the subclasses are *Deaf*, *Deafend* and *Hard_of_hearing*. The subclasses refer to the severity of the disability. The ADOOLES ontology also contains a class called *SeverityOfDisability* under the *Disability* class which is not found in ADOLENA. This class mainly states the severity of each disability and has values *Mild*, *Moderate* and *Severe*. The severity is important as it determines which format a learning resource should be recommended to a student with a particular disability. A student with severe visual impairment (blindness) could thus be recommended learning resources which are in audio, text and Braille format and not video as they will not be able to see the video and its subtitles.

The *MentalHealthDifficulty* class in ADOOLES contains subclasses such as *Anxiety*, *Autism*, *Depression*, *EatingDisorder*, *Obsessive-compulsiveDisorder*, *Phobia*, *Post-traumaticStressDisorder* and *Schizophrenia*. Knowledge about this disability could inform what assistive mechanism (e.g. Support Worker) can be recommended to a student with this disability. In ADOLENA however, the equivalent class *MentalDisability* contains the subclasses *Autism*, *Epilepsy* and *IntellectualDisability*.

HESA classifies epilepsy as an Unseen disability that is why the class *UnseenDisability* was added to ADOOLES as will be discussed below.

The *MobilityDifficulty* class (which in ADOLINA is known as *PhysicalDisability*) contains *LowerLimbMobilityDifficulty* and *UpperLimbMobilityDifficulty* subclasses. The knowledge stored in the ontology about this disability informs decision on how the interface of the e-learning system should be designed for a student with upper limbs mobility difficulty and how the physical environment where learning takes place should be designed to meet the needs of a student or staff with lower limb mobility difficulty such as a wheelchair user or one with an amputated limb who uses crutches. In ADOLINA, the class *PhysicalDisability* contains the following more specific subclasses *Achondroplasia*, *Amputation*, *Cerebral_palsy*, *Dystonia*, *Guillaume_Barre*, *Hemiplegia*, *Kyphosis*, *Multiple_Sclerosis*, *Muscular_dystrophy*, *Osteogenesis_Imperfecta*, *Paraplegia*, *Poliomyelitis*, *Quadriplegia* and *Spina_Bifida*.

The *SpecificLearningDifficulty* class is a new class which is only found in ADOOLES as it deals with learning and contains the subclasses *AttentionDeficitDisorder*, *Dyscalculia*, *Dysgraphia*, *Dyslexia* and *Dyspraxia* as used by HESA. *SpeechDifficulty* in ADOOLES contains *Dumb* and *Stuttering* as subclasses. This class in ADOLINA is known as *SpeechDisability* and contains the subclasses *Little_or_No_Speech* and *Stuttering*. Knowledge about this disability in the ontology will inform decision that such students should have alternative input devices other than speech-to-text, voice recognition or other methods requiring speech as input.

UnseenDisability is unique to ADOOLES and contains the subclasses *Asthma*, *Diabetes*, *Epilepsy* and *HIV-AIDS* which is different from the ADOLINA ontology. In ADOLINA, epilepsy is classified as a mental disability whereas HESA classifies it as

an unseen disability. So, ADOOLES adopted HESA's classification as HESA deals with education.

The *VisualImpairment* class in ADOOLES contains *Blind* and *PartiallySighted* as subclasses. In the ADOLINA ontology, the equivalent class *VisualDisability* contains the subclasses *Blind* and *LowVision*. While partial sight could be synonymous to low vision, HESA uses the terminology partial sight, hence ADOOLES adopted same terminology. Partial sight could also be referred to as low vision while blindness is linked to the severity type *Severe* in the ADOOLES ontology.



Figure 18. Class Disability of ADOOLES Ontology (OWL Viz plugin)

e) The Person Class

The *Person* class (Figure 19 and Figure 20) is an important class in the ontology as the person (in this case the learner) is central to the ontology and to the e-learning system as everything relates to them. This class is not found in the ADOLENA ontology, so it is completely new and was included to capture some important information about the learner, including the types of disabilities they have, in order to better provide personalisation of learning resources. The subclasses include *Email* which is the email address of the individual, *Name* which is the individual's full names, *Password* which is the password used to access the e-learning or other system and which could be used in resetting their password, the *Profile* which contains all these information and other additional information, the *Role* which contains *Student* and *Administrator*.

```
<owl:Class rdf:about="#Person">
  <rdfs:subClassOf rdf:resource="#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#hasDisability"/>
      <owl:someValuesFrom rdf:resource="#Disability"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

Figure 19. RDF/XML representation of the *Person* class

The administrator is responsible for managing the users of the system, the course, and learning resources. The student on the other hand, accesses the courses and services that are provided by the system and reports any difficulties to the administrator who resolves it. The *Person* class also contains *Username*, which is the username used by the person to log in to the e-learning system interface.

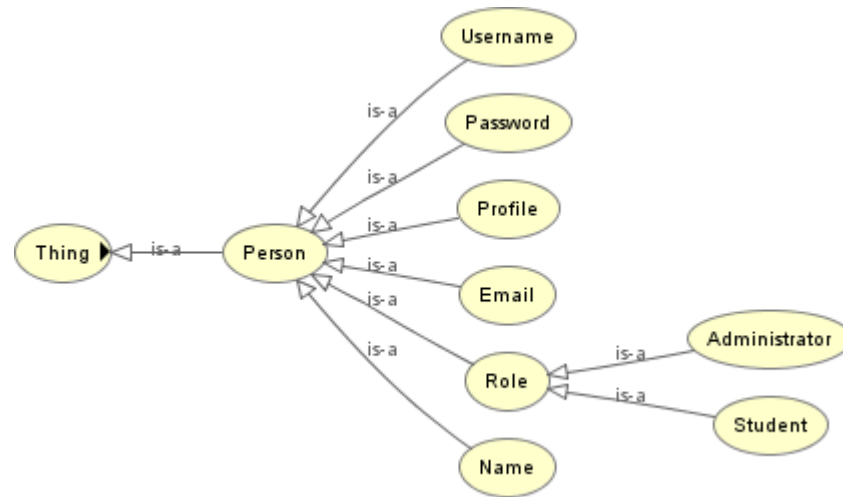


Figure 20. The Person Class

f) The Services Class

The *Services* class (Figure 21 and Figure 22) represents the different types of services offered at the university which could be beneficial to students. This class was necessary because from working at a Student Support Service in a university, it was found that students with disabilities often visit the Service to access various services, thus it would be important to capture information about these Services which could be recommended to students. Such services help the students in their learning. The main subclasses of the *Services* class are *Accommodation*, *Leisure*, *Study*, *FinancialSupport* and *Social*.

```

<owl:Class rdf:about="#Services">
  <rdfs:subClassOf rdf:resource="#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#isAccessedBy"/>
      <owl:someValuesFrom rdf:resource="#Person"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

```

Figure 21. RDF/XML representation of the *Services* class

These services have been derived from the various services offered to students at university. Some of the services have been merged under these topics, for instance, Study Advice will be found under the subclass *Study* alongside Library Services and

Examination Support which are each offered by separate services at the university. The main subclasses are seen as the main services offered by the university which could be accessed by students with disabilities more regularly. Students with disabilities need accommodation that is suitable for their specific needs. A student with a wheelchair will therefore need accommodation that is accessible with a wheelchair and preferably not too far from the university so that they can easily access lecture halls on time and with minimum efforts. The accommodation needs to be suitable to their needs such that they can comfortably move around and do daily tasks without much difficulty.

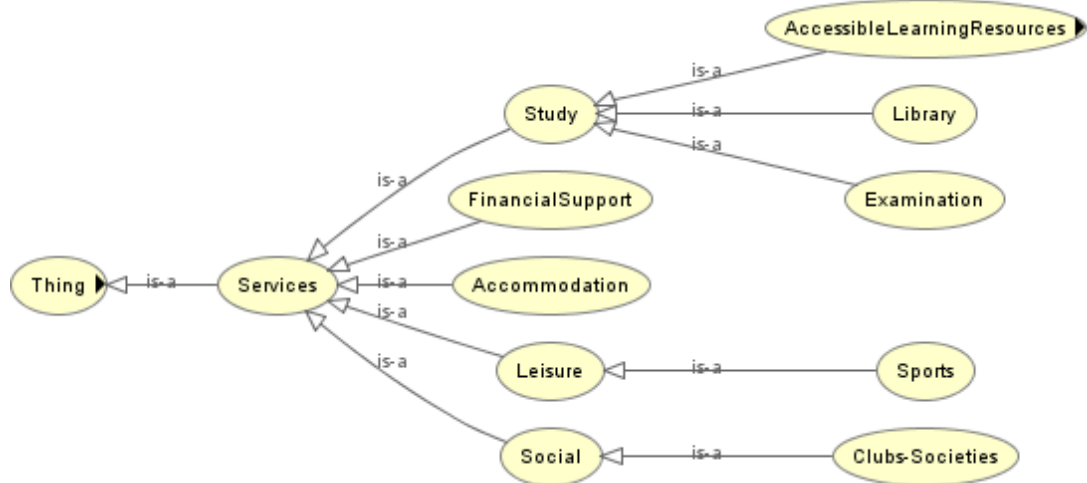


Figure 22. The Services Class

To study well, students with disabilities may also need some leisure activities that will also help them reduce some stress they may have. This could be done by engaging in some sporting activities. Nevertheless, some of the sports could not be suitable for their conditions. A wheelchair user for instance will not engage in football whereas they will be able to play basketball on their wheelchair. There is therefore the need to recommend suitable sports (although nowadays, there are many of such sports that are played by wheelchair users). To be able to study at an equivalent level, students with disabilities need access to services providing support with accessing the library, examination support through the Disability Services as well as information on accessible course

materials. As many students with disabilities get financial assistance from the government through the Disability Living Allowance (Ellis et al., 2008), they will need to know about this financial assistance through a recommendation system. The social needs of students with disabilities also need to be taken care of through the clubs and societies existing at the university. Information on the various clubs and societies could also be very helpful to them.

4.6.3 The Ontology Properties

ADOOLES contains some object properties (Figure 23) which relate two or more classes. This is in the form of domain and range relationships with the first class being the domain while the second class is the range.

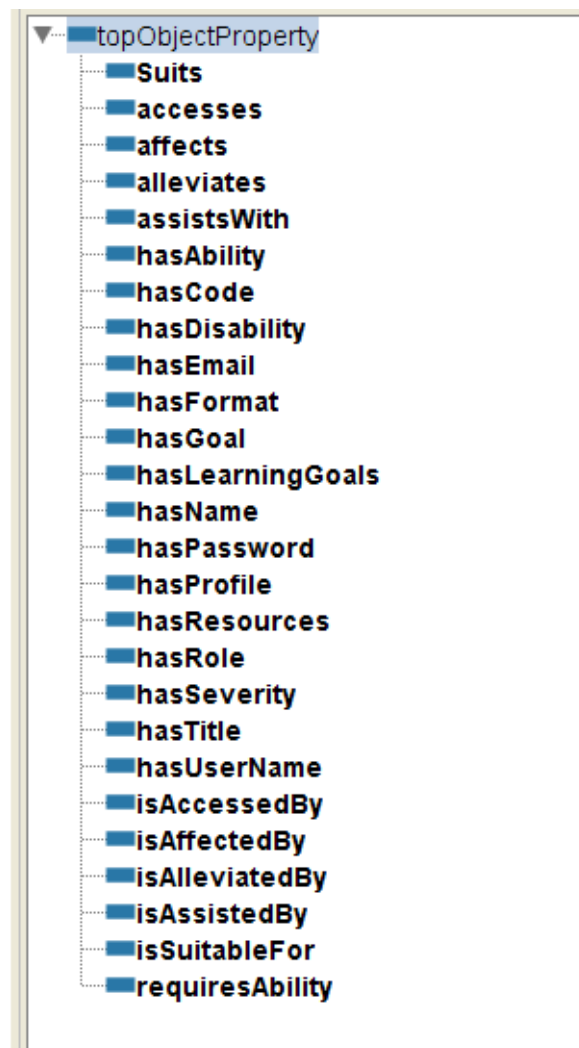


Figure 23. ADOOLES object properties

For instance, the *isSuitableFor* property which is only found in ADOOLES links the domain *LearningResourceFormat* to the Range *VisualImpairment* as shown in Figure 24.

```
<owl:Class rdf:about="#Audio">
  <rdfs:subClassOf rdf:resource="#LearningResourceFormat"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#isSuitableFor"/>
      <owl:someValuesFrom rdf:resource="#VisualImpairment"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

Figure 24. ADOOLES *isSuitableFor* property

This could be interpreted as individuals who are members of the class *Audio* are such that elements relating to them via the *isSuitableFor* property must be *VisualImpairment*. In this code fragment, *isSuitableFor* is a restrictive property. It can be seen that *Audio* which is a *LearningResourceFormat* is suitable for an individual with visual impairment. Many of such restrictive properties have been used in the ontology. This is important because if such restriction is not used, the wrong information could be recommended to an individual. For instance, if restriction is not placed on the learning resource format, a blind student could be recommended a learning resource in video format while a deaf student could be recommended a learning resource in audio format. In each case, they might not access it and it will thus be useless and the system will not be accessible to these students.

Some of the properties in the ADOOLES ontology have inverse relationships with other properties. For instance, *isAlleviatedBy* which is a property that is only found in ADOOLES has an inverse relationship with *alleviates*, another property unique to ADOOLES and is expressed with the element *owl:inverseOf* as shown in Figure 25.

```

<owl:ObjectProperty rdf:about= "#isAlleviatedBy">
    <owl:inverseOf rdf:resource= "#alleviates"/>
</owl:ObjectProperty>

```

Figure 25. Inverse property in ADOOLES

Thus in the ontology, “*AssistiveMechanism alleviates some Disability*” and “*Disability isAlleviatedBy some AssistiveMechanism*”. Some properties and their restrictions are shown in Figure 26.

```

<owl:Class rdf:about= "#AssistiveMechanism">
    <rdfs:subClassOf rdf:resource= "#Thing"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource= "#assistsWith"/>
            <owl:someValuesFrom rdf:resource= "#Ability"/>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource= "#alleviates"/>
            <owl:someValuesFrom rdf:resource= "#Disability"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>

```

Figure 26. Restrictive properties in ADOOLES

Amongst the properties used in ADOOLES shown in Figure 23, the following properties were adopted from the ADOLINA ontology: affects, assistsWith, isAffectedBy, isAssistedBy and requiresAbility.

4.7 Limitations of the ONTODAPS Model

The model presented herein has the following limitations:

The ONTODAPS model relies on the learning materials available within a repository to be able to recommend suitable materials to the learner. If an appropriate format of learning material is not present, it will not be recommended. The learning materials are

not automatically generated by the system. The ability to generate an appropriate format from the existing learning materials will be a very useful functionality.

In relation to the learning materials that are manually produced, the learning materials are semantically annotated by the author who in this case could be a lecturer or an administrator, without input from the learner. Thus, some of the learning materials retrieved may not be relevant to some learners if they are not appropriately tagged as discussed in Chapter 6. To solve this issue, the ability for learners to collaboratively tag learning materials which are then recommended based on similarity measures will be an important addition. Even with this, the individual learner also needs to be given the ability to tag learning materials that are suitable to them.

4.8 Summary

This chapter has presented the design of an ontology-driven disability-aware model for personalising and managing learning resources for students with and without disabilities in an educational context. To develop this model, inclusive design and ontology-based approaches to facilitate retrieval and presentation of learning materials were considered and literature presented to support these. The system architecture was also developed and a presentation of the ontology that drives this system was expounded.

Chapter 5 will show how the ONTODAPS model works in personalising e-learning for students with and without disabilities by presenting them with specific learning materials that are suitable for them based on their disability type and learning goals. This is presented through some case studies. Before then, the testing strategy of the model will be articulated.

Chapter 5: Case Studies

5.1 Overview

Chapters 2 and 3 introduced some issues related to existing learning environments which make them difficult to use by students with disabilities. The previous chapter focused on presenting a solution to some of the problems raised in those chapters through the ONTODAPS model which can enable learning resources to be personalised for both students with disabilities and students without disabilities based on their learning needs and disability type. The ADOOLES ontology which is used to provide such personalisation and to drive the entire system was also presented.

As stated in the objectives in Chapter 1, this chapter will show how the ONTODAPS model works for three main cases. Before that, the evaluation strategy will be explained and then some sample data will be used together with sample queries and algorithms to show how personalisation is achieved. The case of a student without disability will be presented, then a student with multiple disabilities and one with a single disability. The results of the personalisation that is offered will be presented in the case studies. Chapter 6 will deal with using real users to evaluate the model.

5.2 ONTODAPS Evaluation Strategy

Before presenting the case studies to show how ONTODAPS functions for various individuals, this section articulates how the model will be evaluated both in this chapter and in Chapter 6. Evaluation helps to quantify and qualify the effects of a new educational intervention on the learning process and outcomes (Schleyer and Johnson, 2003). According to Yin (1984), the research question is the most important condition for differentiating among the various research strategies (how evaluation will be done).

It is therefore fitting to revisit the research hypothesis, aim, objectives and the specific question related to the evaluation of this model in order to contextualise it.

5.2.1 Research Hypothesis, Aim, Objectives and Question Revisited

In Chapter 1, the research hypothesis, aims, objectives and questions were presented. The hypothesis stated that:

Learning materials can be personalised for learners with disabilities, including those with multiple disabilities by developing a model that allows the learning environment to present learners with materials in suitable formats while considering their learning needs.

The research aim was to show how learning materials could be adapted to the personal needs of a learner by developing an approach that allows for personalisation of learning materials through a consideration of the disability type and learning goals of the learner. Personalisation in this case is recommending specific learning materials to learners in the formats that are suitable to them considering their special needs arising from their disability and their learning needs, determined by their learning goals. The research aim led to several objectives, one of which was to demonstrate through case studies how the e-learning model provides personalisation for single and multiple cases of disabilities and for a student without disability. Some questions also arose from the research objectives, one of which stated:

How does the model provide personalisation of e-learning materials for students with disabilities?

Chapter 4 explained how the ONTODAPS model functions but did not give some practical examples. This can be clearly explained through the use of specific cases. According to Yin (1984), case studies, a way of articulating an empirical topic are used

to answer the *why* and *how* research questions about a contemporary set of events, over which the researcher has little or no control of behavioural events. "How" and "why" questions according to Yin (1984) are more explanatory and likely lead to the use of case studies, histories, and experiments as the preferred research strategies. Thus, it is fitting to use a case study approach to answer the above question.

According to Gable (1994) citing Benbasat et al. (1987), case studies in information systems research have the following strengths: (1) the researcher can study information systems in a natural setting, learn about the state of the art, and generate theories from practice; (2) the method allows the researcher to understand the nature and complexity of the process taking place; and (3) valuable insights can be gained into new topics emerging in the rapidly changing information systems field. Thus, this chapter, through some case studies on students with and without disabilities will show how learning materials can be personalised for students. It thus presents a functional evaluation of the ONTODAPS model. Nevertheless, as Kitchenham et al. (1995) note, "a case study can show you the effects of technology in a typical situation, but it cannot be generalized to every possible situation". Also, Gable (1994) citing Kerlinger (1986) noted three major weaknesses of qualitative research (e.g. case studies) as: (1) the inability to manipulate independent variables, (2) the risk of improper interpretation, and (3) the lack of power to randomize. Lee (1989) also identifies four weaknesses of this approach which include a lack of controllability, deductibility, repeatability and generalizability. Chapter 6 will therefore focus on experimental evaluation, producing both quantitative and qualitative results that will be used to support the results from this chapter. The other advantage of experimentation is that of rigor and the fact that the data can be statistically computed and used to support claims about the model.

5.2.2 Evaluation with Experts

The ONTODAPS model was implemented through a visual interface as will be discussed in the case studies section of this chapter. Albion (1999) states that "it is axiomatic that software of any type should meet basic standards for usability. In pursuit of this goal, usability inspection methods for user interface evaluation can be applied to educational software". Thus, the resultant system would need to be tested to see if users can interact with it with very little difficulties (ease of use), in addition to experimentally evaluating the model that was presented in Chapter 4.

In Chapter 1, one of the objectives was to implement the prototype of the model that was designed in Chapter 4, while another objective was to evaluate the model using various tests, including heuristic evaluation. Thus heuristic evaluation will ensure that the implemented interface meets the required usability standards such that it will allow users to interact with the system and successfully accomplish specific tasks without much difficulty. Nielsen (2005) defines heuristic evaluation as "a systematic evaluation of a user interface design for usability". Heuristic evaluation relies on the judgement of the inspector who follows some guidelines (heuristics) to evaluate the interface. Typically, about 5 evaluators are sufficient to find most of the usability problems that may exist within the software. Heuristic evaluation is thus a cost-effective way of evaluating a user interface design. Considering the ONTODAPS system, Nielsen's ten heuristics (Nielsen, 1994) will be adapted for evaluation. The suitability of heuristic evaluation for pedagogical software evaluation, which includes some of the results from the evaluation of ONTODAPS that will be presented in Chapter 6 has been established and published in Brayshaw et al. (2014).

In addition to evaluating the user interface design, some of the *educational design heuristics* (Quinn, 1996) will also be used to evaluate the educational design of

ONTODAPS in a similar manner to Granic and Cukusic (2011) and Albion (1999). Squires and Preece (1999) proposed heuristics that consider usability in the context of learning with the notions of cognitive and contextual authenticity forming the basis of developing their heuristics. Some of these heuristics will also be adapted for evaluating ONTODAPS. These heuristics will be incorporated in a set of guidelines given to the expert evaluators to evaluate ONTODAPS heuristically. A full list of the heuristics, including their source is shown in appendix G.

A user guide to the ONTODAPS e-learning system was prepared in three different formats (audio, video and text) so that evaluators could choose which format they preferred. A computer dedicated for this evaluation was set up in a quiet room and had speakers and headsets in the event that evaluators wanted to listen to audio or video. Evaluators were selected amongst university lecturers who have experience in human-computer interaction including special needs and have been evaluating student work in interface design. These made good candidates for evaluation because as lecturers, they were qualified to assess the educational value and the usability of the software in heuristic evaluation. The evaluators were asked to go through the guide and to interact with the system at least twice, perform some specified tasks and then evaluate the ONTODAPS visual interface using the heuristics and to fill in a questionnaire that enabled them to rate the implemented software.

5.2.3 Evaluation with Learners

As discussed earlier, experiments and case studies are suitable for answering the *why* and *how* research question (Yin, 1984). The experimental evaluation in Chapter 6 will thus focus on evaluating the ONTODAPS model through a suite of tests. The tests are designed to verify if the ONTODAPS system is able to provide learners with learning materials that are appropriate to them. That is, if the system recommends the correct

format of materials based on the learner's disability type and learning goal. Thus, the results will be used to confirm the results from the case studies that will be presented in Section 5.8. The test bed will be divided into a baseline test (without software intervention in order to establish a means of comparison) and a primary test (with the intervention of ONTODAPS) similar to Costello (2012). According to Schleyer and Johnson (2003) comparison-based educational software evaluation is very common. A few students with disabilities will be used to evaluate the model. This experiment will be small in scale. Kitchenham et al. (1995) suggest that "by their nature, since formal experiments must be carefully controlled, they are often small in scale".

5.2.3.1 Baseline Test

As already mentioned above, the ONTODAPS test suite was designed in order to evaluate if the system allows learners to have learning materials in the correct format that is suitable for them, considering their disability type and learning goals. This presentation of information to the learners is accomplished through using ontologies to model the courses and learners and using various algorithms to be able to present specific learning materials to individuals through the personalisation agent as discussed in Chapter 4 and in the case studies in Section 5.8.

Unlike with case studies where the researcher has no control over behaviour, in the experimental evaluation, the researcher has some control and is able to manipulate variables. The baseline test in this thesis will involve students retrieving learning materials from a repository of about 100 learning materials. Essentially, they will have the task of being able to retrieve learning materials that enable them achieve a specific learning goal and to identify which of those materials retrieved are of the correct format for them, considering their disability type. For the purpose of this test, the materials will be available in either video, audio or text format. The text format chosen here will be the portable document format (PDF). These are just formats chosen for this test, but as

demonstrated in the case studies, this could be applied to allow for recommendation of any format of learning material found in the repository such as Braille, HTML and other formats.

The learning material formats in the baseline test will serve as an indication of the most appropriate format which the learners consider are best for them, which will be compared to those which will be retrieved in the intervention test with ONTODAPS in a similar way to Costello (2012). For instance, a learner with dyslexia who has the goal to improve their knowledge on the software Inspiration may retrieve various learning materials related to Inspiration from the repository in audio, video or text format and then indicate which format is appropriate for them. If they indicate that audio and video are appropriate to them, this result will be compared to that obtained using ONTODAPS. Additionally, their ability to retrieve all the learning materials related to that goal will also be compared with the results from the intervention test.

For the baseline test, learners will be asked to retrieve learning materials that enable them to improve their knowledge on three subjects: Biology, Inspiration and Read & Write. They will also be asked to indicate which format is suitable for them. Learning materials for these subjects will be prepared and available in audio, video and text formats and placed in a repository. To test how ONTODAPS performs in recommending the correct learning materials in the appropriate format, the learning materials in the repository will not only be those covering the above subjects but will also include learning materials on subjects that are not related to the above. The assumption here is that in a typical learning environment, there may be a huge number of learning materials on various subjects, requiring the learner to select the materials that are relevant to their needs. So, it is important to simulate this.

5.2.3.2 Intervention Test

In the intervention test, students were asked to use ONTODAPS to retrieve various learning materials on specific subjects. Specifically, they were asked to register on the system but without any identifying information. The intervention test just like the baseline test had three tests which asked learners to retrieve materials that enable them to (1) learn Inspiration, (2) learn Read & Write, and (3) learn Biology. Once this was done, they were asked to retrieve the learning materials and then to record how many materials were retrieved, how many were relevant, the number of irrelevant materials, and the formats of materials retrieved and to state if they were suitable for them. The data from this experiment were collected and analysed. The precision and recall were calculated in order to determine the effectiveness of the personalisation offered.

As this test was conducted in the same way as the baseline test, the results were used to compare with the results from the baseline tests with the assumption that any changes observed would be as a result of using ONTODAPS.

5.2.4 Measuring the Performance of ONTODAPS

The two most widely used parameters for measuring the performance of a retrieval system are recall and precision (Salton, 1992). Considering the baseline and intervention tests, quantitative data will be collected and then the three performance indicators of precision, recall and F-score will be measured in order to evaluate the accuracy of the personalisation provided by ONTODAPS. From a probability perspective, Goutte and Gaussier (2005) define *precision* as "the probability that an object is relevant given that it is returned by the system" and *recall* as "the probability that a relevant object is returned". Keen (1992) defines precision as the relevant materials retrieved as a proportion of the total materials retrieved while recall is the number of relevant materials retrieved as a proportion of the total relevant or total retrieved. Salton (1992) agrees with this definition, stating that precision is the

proportion of retrieved items that are relevant while recall is the proportion of relevant items that are retrieved.

According to Goutte and Gaussier (2005), precision (p), recall (r) and F-score (F) are calculated as follows:

$$p = \frac{TP}{TP + FP} \quad (1)$$

$$r = \frac{TP}{TP + FN} \quad (2)$$

Where:

TP stands for true positive. Within the context of this experiment, TP will be the number of correct and relevant learning materials that are retrieved.

FP stands for false positive. Within the context of this experiment, FP will be the number of non-relevant learning materials that were retrieved.

FN stands for false negative. This represents the number of relevant learning materials that were not retrieved.

TN stands for true negative. This represents the number of non-relevant learning materials that were not retrieved.

The F-score can be calculated from the precision and recall values as follows:

$$F = \frac{2pr}{p + r} \quad (3)$$

Manning et al. (2008) present the following contingency table to clarify the above notions as shown in Table 2.

Table 2. A contingency table for precision and recall (Manning et al., 2008)

	Relevant	Non-relevant
Retrieved	true positives (TP)	false positives (FP)
Not retrieved	false negatives (FN)	true negatives (TN)

According to Manning et al. (2008), “the advantage of having the two numbers for precision and recall is that one is more important than the other in many circumstances”. For instance, they explained that web surfers have a preference for high precision (first page results should be relevant to them but they would not want to go through all the relevant results). On the other hand, they identify that intelligence analysts prefer getting as high recall as possible. Since precision and recall trade off against one another, Manning et al. (2008) thus consider the F measure (or F-score) as the harmonic mean of precision and recall, which is a single measure that trades off precision versus recall. They also state that “the default balanced F measure equally weights precision and recall”.

Measuring precision and recall in the experiments in Chapter 6 will enable the measurement of the effectiveness of the algorithms that will be presented later on in this chapter as part of the personalisation agent (Frei and Schauble, 1991). Given that precision and recall vary between 0 and 1 for any query, Hull (1993) suggests that average precision and average recall is much more meaningful. Thus, in the experimentation in Chapter 6, this thesis will make use of average values. This is also important as there will be different values obtained from participants in the study and hence it is imperative to compute the average values and to make inferences on these.

5.2.5 Other variables

In addition to measuring the system performance through precision, recall and F-score as described above, other variables will also be measured. Jones et al. (1999) developed the context, interaction, attitudes and outcomes framework (Jones et al., 1996) for evaluating computer-assisted learning. The interaction component involves observing users as they interact with the software, which is what will be done during the evaluation of the ONTODAPS model in Chapter 6. As users are asked to retrieve the learning materials as described in the test beds above, the researcher will observe them in order to understand their preferences of format of learning materials and what they consider to be of interest to them. In measuring interactivity, participants' opinions on interface consistency will be sought.

Jones et al. (1999) also suggested to measure students' perception and attitude towards the software. This will be taken into consideration in this evaluation and will be measured as their interest (beneficial, relevance, aid learning experience and whether they would use the software again if its functionality were available in another LMS/VLE) and confusion as carried out by Costello (2012). Qualitative questions will be asked through a questionnaire at the end of the interaction with ONTODAPS. Through the questionnaire, the data collected can be used to determine if the participants enjoyed the user interface and if they think the model can help them improve their learning (Shani and Gunawardana, 2011).

Dalrymple (1991) suggests that "the satisfaction of the human user rather than the objective analysis of the technological power of a particular system may be a criterion for evaluation". This is what is being evaluated in most usability studies. The heuristic evaluation of ONTODAPS deals with this from the point of view of experts while the student participants also evaluate their satisfaction with the system through post

interaction questionnaires. The questionnaire that student participants will fill at the end of the experiments also measures user satisfaction. Thus, usability will be measured considering: *learnability* (how easy it is for first time users to use ONTODAPS), *efficiency* (time taken to accomplish specific tasks), *memorability* (how easy it is for learners to re-establish proficiency with ONTODAPS after a period of not using it) which will be tested through some questions about how to accomplish specific tasks with the system, *errors* (number of errors made while trying to carry out the set tasks) and *satisfaction* (how satisfied learners are with the system).

5.2.6 Limitations

At the onset of this experiment, the aim was to have 30 students with disabilities evaluate the model in order to provide greater insights into the impact of the ONTODAPS model. However, it was difficult to recruit more than 18 students for the evaluation even after the involvement of the Student Academic Success Service (SASS) and the Centre for Students with Disabilities (CSD) at the University of Ottawa where the experimental evaluation with students took place. However, as earlier mentioned, Kitchenham et al. (1995) suggested that formal experiments need to be small in scale in order to carefully control them. Thus, smaller scale sampling was used in the experiments in this thesis. Small scale samples are not uncommon in computer science software experiments. Nyhof-Young et al. (2002) successfully used small number of participants to evaluate a piece of software, using a wide range of evaluation methods and strategies. Schoner et al. (2005) used 12 students to evaluate the use and re-use of learning objects, while in an experiment to evaluate a mobile keyboard, Lyons et al. (2006) successfully used ten participants. Pi-Hua (2006) used 9 junior college students to evaluate the pedagogical usefulness of a pronunciation oriented software and found that the software was able to differentiate between students at the beginning and intermediate levels. The disadvantage of using such small samples however is that the

results obtained cannot be generalised across the target population. Thus, caution should be taken in interpreting the results from evaluating the ONTODAPS model in Chapter 6 with 18 students. Because of the small sample size, only 2 students with multiple disabilities participated in the study. Coincidentally, the two students with multiple disabilities had the same types of disabilities, thus there was not enough diversity in terms of multiple disabilities. Thus, although this study aims to provide a solution to the difficulties of students with multiple disabilities in existing learning environments and that the results from using a small sample size could be meaningful, such results could not be generalised across the entire population without further testing with a larger and more diverse group of students across various institutions.

In measuring the performance of ONTODAPS, precision and recall were used as already discussed above. These measures also have their limitations. Dalrymple (1991) argues that both precision and recall measure the system's performance in retrieving items that have been predetermined as being relevant to the information need but do not consider how the information will be used or whether the user considers that the retrieved documents will fulfil their information need. To address this limitation of using precision and recall, in the baseline and intervention studies, participants will be asked to determine if the learning materials retrieved from the repository both through user effort in the baseline experiments and through ONTODAPS in the intervention experiments, are of the correct format for them, considering their disability type and learning goals. Learners can only access and read the information if it is in a format that is suitable for them or compatible with any assistive technology they may be using.

5.3 Modelling disability with semantic web technology

This section considers the various components of the personalisation process for a student in the ONTODAPS system. The components involved in providing effective

user personalisation include: the user profile, the ADOOLES ontology, the inference engine, the personalisation agent and the learning resources which are all manipulated via the user interface as shown in Figure 27. To accomplish this personalisation, ONTODAPS uses ontologies to annotate learning resources and to construct the user profile. The personalisation agent and inference engine then provide the personalisation through various queries and algorithms.

Information about the user is collected through ONTODAPS graphical user interface (GUI) and stored in the ontology as their user profile. The profile also contains the type of disability of the user which is linked to the various disabilities in the ADOOLES ontology. This information is used by the personalisation agent to recommend specific learning resources to the user.

To accomplish such personalisation, the personalisation agent makes inferences on what format of learning resources should be presented to the learner based on the type and degree of their disability. The personalisation agent contains algorithms which scan through the available learning resources, extract and present specific resources compatible with the learner's disability.

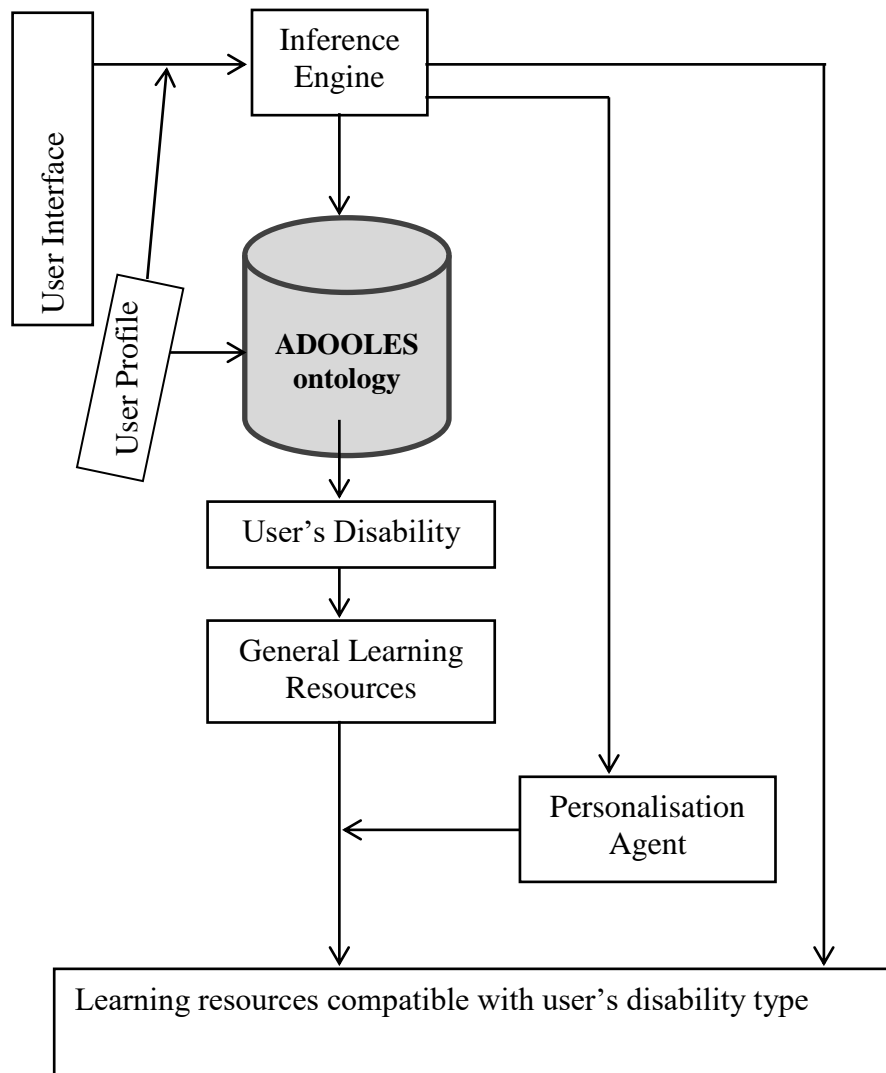


Figure 27. Ontology-based personalisation for a student with disability

The above figure provides a general and high level overview of how personalisation is accomplished in ONTODAPS. To understand how this personalisation actually works, some key components of the system will be isolated and their constituent components and functions discussed, beginning with the user profile.

5.4 The User Profile

The user profile is a key player in personalising learning resources for the learner and hence it is worth examining in detail the content of the user profile, its relevance in

providing the correct personalisation and how the profile is created particularly using an ontology-based approach.

5.4.1 Modelling the user

The first point of interest when examining the user profile is the source of its contents. The user profile information could be indirectly or directly collected from the user. Indirectly, the information could be gathered from the user's browsing patterns. The usage data obtained from such patterns could be used to provide personalisation. For instance, a learner may be known for accessing a specific learning resource in a video format each time they log in to an e-learning system. It could thus be inferred from their behaviour that their preferred format for viewing learning resources is video and hence this information could be extracted and stored in their user profile. The information could also be gathered through the user's rating of learning resources. A higher rating for a specific resource or topic of interest might indicate preference for that resource.

The information about the user could also be gathered from the learner providing identifying information to the system, which helps the system provide the correct courses or resources for that learner (Treviranus and Roberts, 2008). Some of the sources of information for the user profile are represented in Figure 28. The disability type includes members such as visual impairment which could be partial sight, low vision, colour blindness and blindness. Also, the degree of disability is important and could be expressed as mild, moderate or severe. Severe cases are considered in this context to be the extreme for that disability. For instance, mild visual impairment could mean the person has some sight (low vision), while severe visual impairment will mean total blindness hence the individual cannot see anything even with medical lenses. The preferences of the individual are mainly represented here as their preferences for the

format of learning resources which could be video, audio or text or a combination of these.

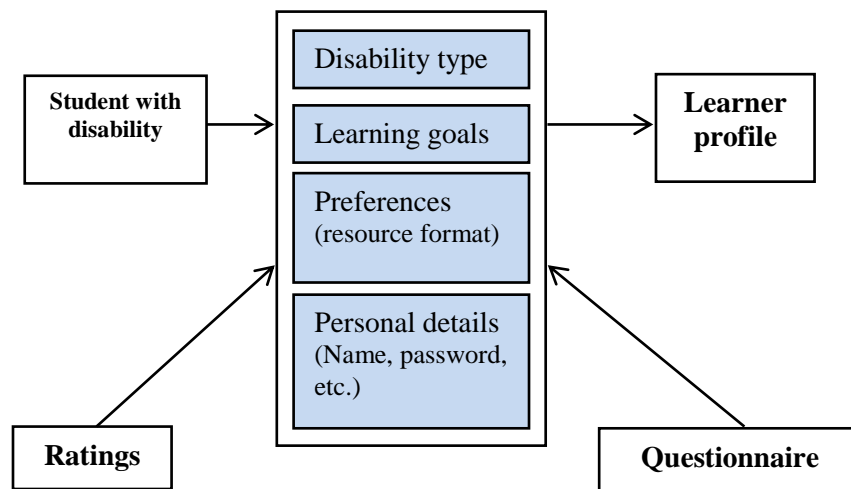


Figure 28. Collecting and storing a learner's profile information

The individual's personal details include their names, password and disability type amongst other information. Directly, this information could be collected through a form with various fields as shown in Figure 29 in the case of an individual with single disability. For an individual with multiple disabilities, once a disability is selected and added, the individual then needs to select the next disability and add.

First Name:	<input type="text"/>	Surname:	<input type="text"/>	Username:	<input type="text"/>
Password:	<input type="text"/>	Confirm Password:	<input type="text"/>	Email:	<input type="text"/>
Disability type: Specific Learning Difficulty <input type="checkbox"/> Visual Impairment <input type="checkbox"/> Hearing Impairment <input type="checkbox"/> Mobility Difficulty <input type="checkbox"/> No Disability <input type="checkbox"/>					
Degree of Disability: Mild <input type="checkbox"/> Moderate <input type="checkbox"/> Severe <input type="checkbox"/>					
Learning Resource Format Preference: Video <input type="checkbox"/> Audio <input type="checkbox"/> Text <input type="checkbox"/>					
<input type="button" value="Submit"/>			<input type="button" value="Cancel"/>		

Figure 29. Collecting user profile information through forms

The information provided by the user then gets added to the ontology, which is then used to provide personalisation. Should an individual develop other future disability they can add it to their profile; the information is updated, enabling ONTODAPS to provide them with the appropriate personalisation.

5.4.1.1 Disability type and degree

The user profile for a learner with disability will need to consider the type and the degree (mild, moderate, severe) of the disability. The type of disability will help to determine what format (audio, video, text, etc.) the learning resource will be presented to the learner. For instance, a learner with visual impairment might be recommended an audio or text resource. As the learner can hear, the sense of sound could be exploited to present them information that is received through their ears. Although text is visual-based, the learner could employ a screen reading software to read the text, thus using their ears to collect the information which is then processed by their brain and assimilated. It is therefore appropriate to present them with a text resource. For a mild case of visual impairment (e.g. partial sight), the user could be able to use a screen magnifier to magnify the text and read it or the information could be presented with an inbuilt ability to increase the text size. A learner with mild dyslexia could accommodate reading relatively long text and might not depend so much on simplified presentations that someone with severe dyslexia might require.

5.4.1.2 Personal details

The user's personal details such as their names, disability type and email are very important identifiers that could be used to identify them and present specific information. By choosing a specific username and password at registration in addition to these personal details, personalisation is further enhanced in that if the username and

password are correct, then the correct details for the individual will be displayed, which gives the assurance that the personalisation provided is for the said learner.

5.4.1.3 Learning resource format

Collecting the correct information about the user's preferred format of information presentation is very important in that it determines if the individual will be able to consume that information or not. For instance, if the profile of a learner with severe hearing impairment indicates that their preferred format is an audio learning resource without captions, then the learner will be unable to access the information because they cannot hear the audio and hence cannot understand what information is being presented. However, such information could be inferred from the user's disability type and its degree and the appropriate learning resource recommended to them.

5.5 User profile knowledge representation

The user profile information already discussed can be modelled using an ontology. The user profile ontology will consist of classes with various properties. The upper level classes are presented in Table 3.

Table 3. Classes of the user profile ontology for a user with disability

Class Name	Description
Person	This class contains subclasses which include the personal details of the individual such as <i>firstName</i> , <i>family_name</i> , <i>username</i> , <i>password</i> , <i>email</i> (mbox), <i>gender</i> .
Disability	This contains the individual's disability. Such disability is fully represented in the ADOOLES ontology and hence could be referenced.
Resource format preference	This is information about the preferences of a user for different formats of resources such as video, audio or text.
Learning goals	The individual's learning goals used for personalisation

This ontology can be represented in RDF-like notation that employs some FOAF¹ (Friend of a Friend) vocabulary as shown in Figure 30.

```
@prefix foaf: <http://xmlns.com/foaf/0.1>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.

_:s1    rdf:type                foaf:Person .
_:s1    foaf:gender             "Male".
_:s1    foaf:firstName          "John".
_:s1    foaf:family_name        "Bull".
_:s1    foaf:mbox                "bulldog@gmail.com".
_:s1    foaf:disability          "Dyslexia" .
_:s1    foaf:resourceFormat      "Video".
_:s1    foaf:resourceFormat      "Text".
```

Figure 30. User profile represented in RDF notation using FOAF vocabulary

The same information could also be represented using a more structured ontology-based format. The above representation which has been expanded to contain additional details such as the learning goals, the degree of the individual's disability and the learning resources is presented in Figure 31.

```
:rdf: type                foaf:Person
:personDetails            "firstname, family_name, gender, username, password, mbox";
:person_concept hasfirstName: "John";
:person_concept hasfamily_name: "Bull";
:person_concept hasGender: "Male";
:person_concept hasfamily_name: "Bull";
:person_concept hasuserName: "jbull";
:person_concept hasmbox: "bulldog@gmail.com";
:person_concept hasDisability: "Dyslexia";
:person_concept hasDisabilityDegree: "mild";

:rdf: type                foaf:LearningGoals
:learningGoals            "How to program, graphics basics, internet safety";
:learningGoal_concept goalOne: "How to program";
:learningGoal_concept goalTwo: "Graphics basics";
:learningGoal_concept goalThree: "Internet safety";

:rdf: type                foaf:LearningResource
:resourceFormat            "video, audio, text";
:resourceFormat_concept prefersFormat: "video";
:resourceFormat_concept prefersFormat: "text";

:resourceName            "programming 1, computer graphics, internet computing";
:resourceName_concept recommendedResource: "Programming 1";
:resourceName_concept recommendedResource: "Computer Graphics";
:resourceName_concept recommendedResource: "Internet Computing";
```

Figure 31. User profile represented in structured ontology-based format

¹ <http://xmlns.com/foaf/spec/>

The above profile represents a male individual known as John Bull with username jbull and email address bulldog@gmail.com. Additionally, John Bull has three learning goals which include: “to know how to program”, “to learn the basics about graphics” and “to understand internet safety techniques”. John also prefers learning resources that are of the format “video and text” given that he has dyslexia. As John’s learning goals are linked to the learning resources, the recommended courses for them to take in order to achieve their learning goals are “Programming 1, Computer Graphics and Internet Computing”.

An implemented profile interface with some sample goals are presented in Figure 32.

The screenshot shows a web application window titled "My Profile" with a menu bar (File, Profile, View, Help) and buttons for "Save Data" and "Refresh".

User Data:

- User Name: jbull (with a "Change Password" button)
- Full Name: John Bull
- Email: bulldog@gmail.com

Disabilities:

- ☒ Have Disabilities
- Specific Learning Difficulty: Mild (with "Add" and "Delete" buttons)
- Type: Specific Learning Difficulty (dropdown)
- Severity: Mild (dropdown)

Learning Goals:

- ☐ This user is a manager.
- Assigned Goal:**
 - G005 : Concepts & techniques of progra
 - G003 : The Internet
 - G006 : Essentials of human-computer int
- Recommended Goals:**
 - G006 : Essentials of human-computer interac
 - G003 : The Internet
 - G004 : Introduce computer games technolog
 - G001 : Insight about the web
 - G010 : Learn Inspiration Software
 - G002 : Develop key IT & Computing skills
 - G011 : Learn Read and Write software
- All Available Goals:**
 - 10001 : A Learning Goal
 - G101 : Fry a Fish
 - G005 : Concepts & techniques of programmin
 - G006 : Essentials of human-computer interac
 - G003 : The Internet

Buttons for "<< Assign", "Remove", and "<< Assign" are also visible.

Figure 32. Implemented profile interface

5.5.1 Retrieving user profile details

Data about the user is stored as their profile as already seen. This data as already discussed is vital for providing personalised resources for the individual. What remains is how to extract this information from the data. To do this, this thesis will consider a

sample dataset for a user and then see how the data could be queried to generate specific results.

5.5.1.1 Sample dataset

Let us consider the following data (information) about a user with a specific learning difficulty - specifically dyslexia - with their Friend of a Friend (FOAF) profile presented using the Turtle (Quest et al., 2010) data format. Turtle is an RDF triple language. The current FOAF (Rzepa and Willighagen, 2008) vocabulary lacks information for modelling disabilities, which could be useful in disability-aware systems. Thus, the examples used here employing this vocabulary have included the disability and learning related terms that were used in the ADOOLES ontology.

In the dataset in Figure 33, *foaf:disability* and *foaf:resourceFormat*, for example have been employed to include people with disabilities in learning through specifying what format of information could be presented to a learner with disability. The sample dataset below shows two different individuals, s1 who is a male with dyslexia known as John Bull and s2, who is a female with visual impairment known as Mary Book.

```

@prefix foaf:    <http://xmlns.com/foaf/0.1>.
@prefix rdf:     <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.

_:s1    rdf:type          foaf:Person .
_:s1    foaf:gender       "Male".
_:s1    foaf:firstName    "John".
_:s1    foaf:family_name  "Bull".
_:s1    foaf:disability    "Dyslexia" .
_:s1    foaf:resourceFormat "Video".
_:s1    foaf:resourceFormat "Audio".
_:s1    foaf:resourceFormat "Text".

_:s2    rdf:type          foaf:Person .
_:s2    foaf:gender       "Female".
_:s2    foaf:firstName    "Mary".
_:s2    foaf:family_name  "Book".
_:s2    foaf:disability    "Visual Impairment" .
_:s2    foaf:resourceFormat "Audio".
_:s2    foaf:resourceFormat "Text".

```

Figure 33. Sample profile dataset for two learners with disabilities

The dataset mainly contains the personal information of both John and Mary and is used to show how the data could be queried to retrieve specific details.

5.5.1.2 Querying the dataset

Specific information about users can be queried in the system using query languages such as SPARQL (SPARQL Protocol and RDF Query Language) (Lee et al., 2011) which is a W3C standard that can be used to query ontologies in RDF format.

Considering the above dataset, the following SPARQL query in Figure 34 will retrieve the last name, gender, disability and format of learning resources for each individual.

```
PREFIX foaf: @prefix foaf: <http://xmlns.com/foaf/0.1>
SELECT ?family_name ?gender ?disability ?format
WHERE {
  { ?x foaf:family_name ?family_name .}
  { ?x foaf:gender ?gender .}
  { ?x foaf:disability ?disability .}
  { ?x foaf:resourceFormat ?resourceFormat .}
}
```

Figure 34. SPARQL query to retrieve user profile details

5.5.1.3 Query results

In the system, the user profile needs to be retrieved after the learner logs into the system. Their details are presented to them, confirming that it is about to present personalised information to them. This is an important aspect as it helps the user to confirm that the details are theirs, otherwise the wrong personalisation will be provided. The above query generates the results in Table 4.

Table 4. Query results from sample dataset

family_name	gender	Disability	resourceFormat
Bull	Male	Dyslexia	Video, Audio, Text
Book	Female	Visual Impairment	Audio, Text

5.6 The Learning Resources

In disability-aware e-learning personalisation, learning resources are personalised for each learner according to their disability type, learning goals and preferences. It is however very important to know what format to present the resources for various disabilities. To understand this, Table 5 provides some guidance as it shows the effects of some disabilities on an individual's learning and the recommended formats of learning resources for various degrees of the disabilities.

Table 5. Disability type, effects and recommended resource formats

Disability type		Effects on individual	Assistive requirements	Recommended learning resource format
Visual impairment	Mild	Low vision, onset of visual problems	Screen magnifier, appropriate colours and combinations	Audio/tape resources, text-based documents, Braille format
	Moderate	Low vision, increasing sight difficulties, sees partially		
	Severe	Blindness, individual cannot see anything	Screen reader, Braille	
Hearing impairment	Mild	Partial loss of hearing	Hearing aids, hearing loops,	Text-based resources, video/audio with captions
	Moderate	Progressive loss of hearing		
	Severe	Complete loss of hearing	Captioning	
Specific learning difficulty	Mild	Difficulties with reading, oral language, writing and mathematics. Memorising and comprehension problems.	Voice recognition software, scanning pens, typing tutors	Video (illustrated and simplified), audio, journalistic style-summarised text-based resources
	Moderate			
	Severe			
Mobility difficulty	Mild	Mild difficulties with movements	Head wand, adaptive keyboards,	Video, audio and text-based resources
	Moderate	Increasing difficulties with movements		
	Severe	Unable to move independently	Mouth stick, voice recognition, eye tracking	
Mental health difficulties	Mild	Anxiety, poor concentration, short term memory difficulties, inconsistent attendance, low self-esteem and depression	Requires a mentor or support worker, emails and texting	Audio, video, text-based resources
	Moderate			
	Severe			
Speech Difficulties	Mild	Slurred speech, stuttering, muteness,	Text-to-speech software, communication boards	Audio, video and text-based resources
	Moderate			
	Severe			

Using semantic web technology to annotate the resources will mean they can be easily referenced, retrieved and presented to the learner. To accomplish this, this thesis will discuss how the resources can be annotated using RDF.

5.6.1 Semantic annotation of learning resources

An e-learning system typically has a means of storing learning resources. These resources might be stored in a database or in a specific repository. Annotating these resources will facilitate retrieval when the system is queried.

Semantic web technologies are effectively used in annotating resources for easy retrieval. The learning resources here are modelled following Brase and Nedjl (2004), using the RDF format having a subject, predicate and object. Let us consider the 08123 Computer Systems module at the University of Hull, created by Mike Brayshaw. The subject, predicate and object of the resource are presented in Figure 35.

Subject: <http://intra.net.dcs.hull.ac.uk/student/modules/08123/default.aspx>
 Predicate: dc:creator
 Object: "Mike Brayshaw"

Figure 35. Subject, predicate and object for module 08123

That learning resource can be fully represented using the XML syntax of RDF. The resource title, creator and format can be represented in RDF as shown in Figure 36.

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:dc="http://purl.org/dc/elements/1.1/">
<rdf:Description rdf:about="http://intra.net.dcs.hull.ac.uk/student/modules/08123/default.aspx">
  <dc:title xml:lang="en">08123 Computer Systems</dc:title>
  <dc:creator>Mike Brayshaw</dc:creator>
  <dc:format>Video, Audio, Text </dc:format>
  <dc:description>Essential hardware and software components of computers</dc:description>
</rdf:Description>
</rdf:RDF>
```

Figure 36. Annotating the learning resource with RDF

5.6.2 Querying the learning resources

Just like in the above example of the user profile, the learning resources could be queried using a SPARQL query to retrieve results. In the ontology-based e-learning system, the user enters their details and is identified by the system before personalised learning resources are presented as shown in Figure 37.

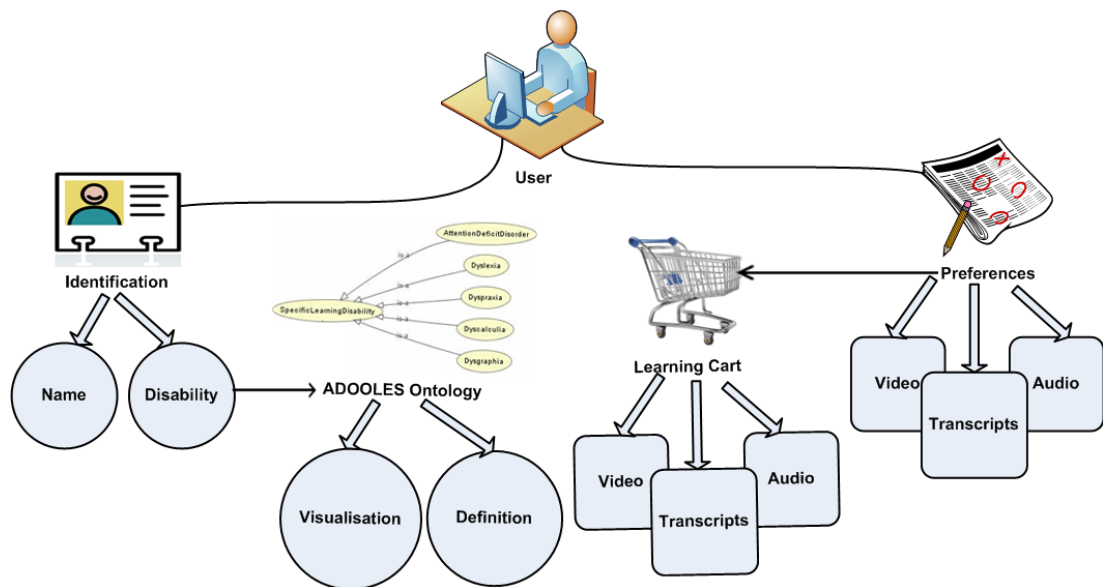


Figure 37. ONTODAPS Learning Resource Personalisation Process

By assigning learning goals to a student, the system can then present the learner with specific learning resources based on information contained in their personal user profile. Let us consider for instance that one of John Bull’s learning goals is to “understand the functionality and architecture of a modern operating system”, the inference engine will be able to infer that this goal is linked to the module “08123 Computer Systems”. This information is then communicated to the personalisation agent, which then queries the system to retrieve that specific module and present to John Bull. Also inferring that John Bull’s preferred formats are “video, audio and text”, and the fact that he has mild dyslexia which means he might not have a great difficulty with any of those formats, the system then enables him to view the resource in any of the formats he prefers.

The sample SPARQL query for retrieving the learning resource is presented in Figure 38.

```

PREFIX foaf: @prefix foaf: <http://xmlns.com/foaf/0.1>
SELECT ?title ?format
WHERE {
    { ?x foaf:title ?title .}
    { ?x foaf:format ?format . }
}

```

Figure 38. Sample query to display the title and format of a learning resource

5.6.3 The query results

The above query for learning resources from the system will retrieve the results shown in Table 6.

Table 6. Results of SPARQL query for learning resource title and format

Title	Format
08123 Computer Systems	Video
08123 Computer Systems	Audio
08123 Computer Systems	Text

The sample implemented interface for retrieval of courses and accessing them in specific formats is shown in Figure 39.

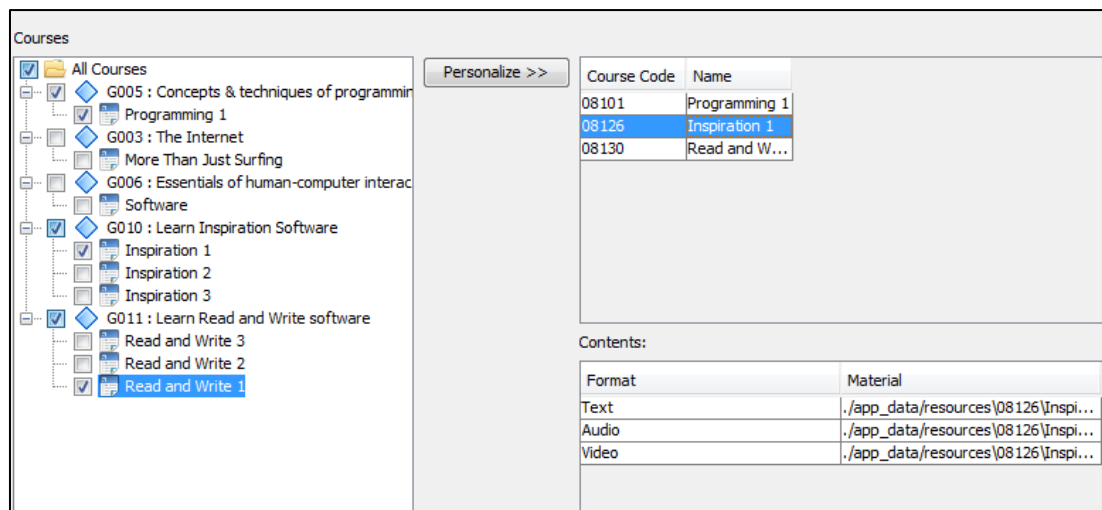


Figure 39. Implemented interface showing query results for learning resources

5.7 The Personalisation Agent

The personalisation agent in the ONTODAPS system is the main agent that enables the learner to be presented with learning resources that are suitable for them. To do this, the agent uses some algorithms to provide personalised learning resources.

5.7.1 Personalisation algorithms

The personalisation agent makes a decision on what resources to present to the learner based on the input information. What is input into the agent is information contained in the profile of the learner which, as already discussed, consists of their disability type and degree, learning goals and preference of the format of learning resources. The agent in return outputs the recommended learning resources in specific formats based on the type and degree of disability. The algorithms and how the personalisation agent provides personalisation will be considered under the case studies section.

5.8 Case Studies

Presenting learning content to students with disabilities could pose a great challenge depending on the type and severity of disability. In some cases, the learner could present with more than one disability (multiple disabilities), which could pose a great challenge to personalisation. As Petrie et al. (2006) observe, the challenge is to design for those with multiple disabilities such as one who is both blind and deaf.

This section will describe some case studies on how ONTODAPS can provide personalisation for various cases of disability.

5.8.1 Case Study on a Student without Disability

For a student without disability, ONTODAPS relies on the learning goals of the individual to provide personalisation of learning resources. Learning goals could be

assigned to the student by an administrator if the student wishes or by the student them self.

ONTODAPS receives input about the learning goals and disability type of the student contained in their profile and queries the ADOOLES ontology containing the learning resources that have been stored in RDF format. At this stage, there are general learning resources which might be numerous, so the personalisation agent is invoked to retrieve specific resources related to the learning goals of the student. As the student has no disability, the system then presents them with the resources in all three formats and they can then choose to view it in any of the formats. The process through which ONTODAPS achieves personalisation for a student without disability is shown in Figure 40.

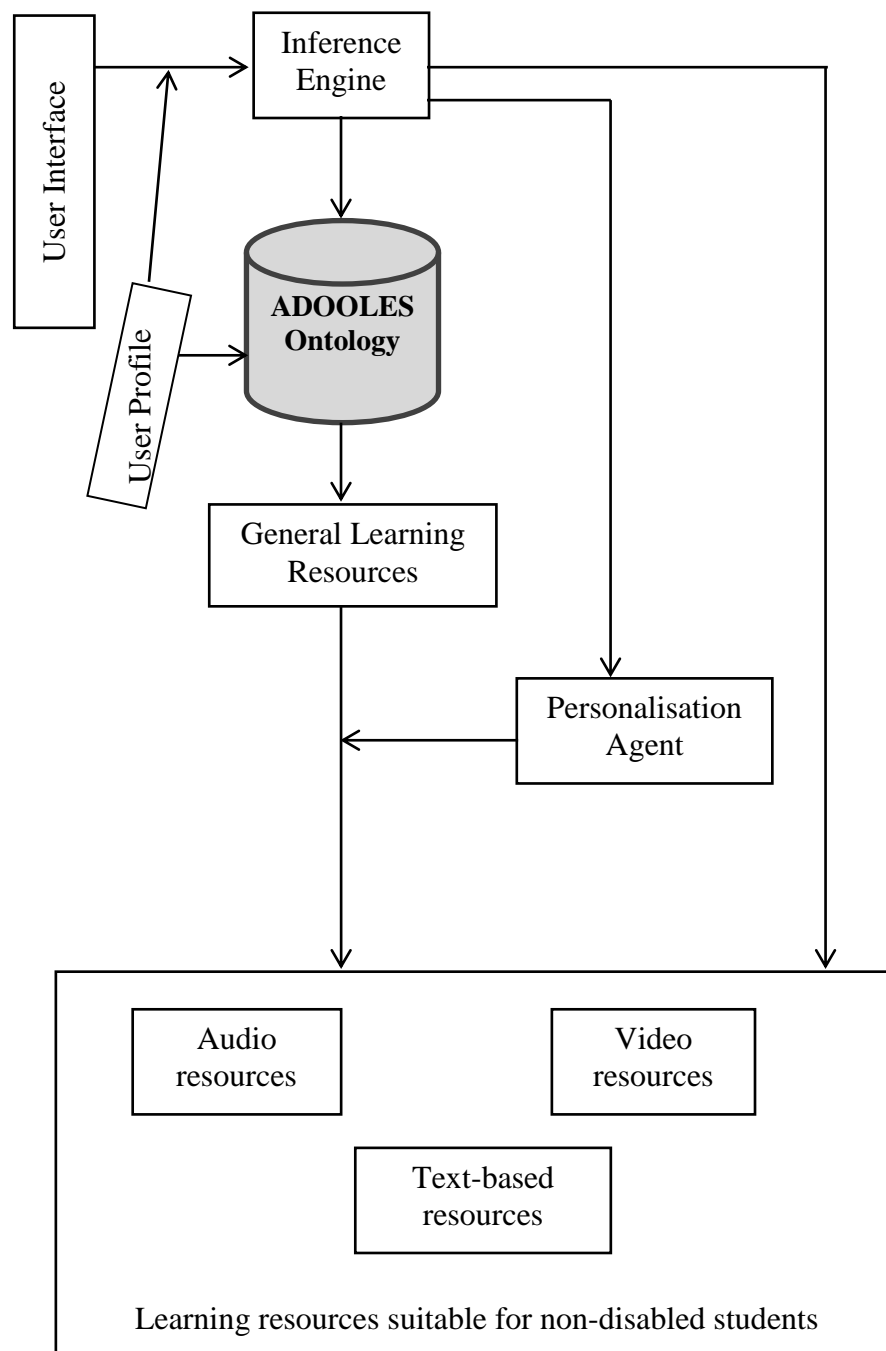


Figure 40. Personalisation for a student without disability

It has been stated earlier that the personalisation agent uses some algorithms to provide personalisation. Let us consider the personalisation algorithm for the case of an individual who has no disability.

To define the algorithm for personalisation, let us assume the following:

Let

F_i be the learning resource format (F_v = video, F_a = audio and F_t = text)

D_i be the type of disability (D_{dys} = dyslexia, D_{bli} = blindness)

R_i be the learning resource (R_{dys} = resources suitable for dyslexia R_{bli} = resources suitable for blindness)

G_i be the learning goal

Since the disability type determines what format the learning resource will be presented to the learner, it follows that D_i maps onto F_i and G_i unto R_i as follows:

$$(D_i \rightarrow (F_i \& G_i)) \rightarrow R_i \text{ ----- (1)}$$

The personalisation agent receives an input and then outputs a recommendation on the learning resources in formats that are suitable for the specific disability type that was input. Therefore, if no disability type is input into the system, no learning resource formats are presented to the user. For a user with no disability, the input is coded as No Disability and the system understands this to be a student without disability. It can then present personalised learning courses based on learning goals.

The main input is information on learning goals as well as disability type, although in this case, the user has no disability, the system still needs to know this in order to provide the correct personalisation. The input and output data are presented in Figure 41.

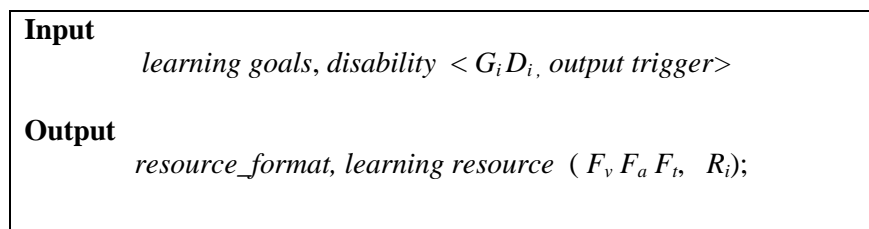


Figure 41. Input and output data in the personalisation agent for a student without disability

Input: the input as seen in Figure 41 is information about the learning goals of the user and their disability type. In this case, the individual has no disability. The input also receives an output trigger or iterator which initiates the process of presenting the personalised results.

Output: the output consists of learning resources in formats that are suitable for a student without disability; in this case, all three formats are presented.

The pseudocode for the algorithm that provides the personalisation is in Figure 42. The personalisation agent having received the information about the disability type and learning goals goes through the available resources.

```

Initialisation
Let  $R_i$  be the learning resources suitable for a student without disability
while ( $D_iF_v \neq D_iF_a$  &&  $D_iF_a \neq D_iF_t$ )
if ( $D_iF_i > 0$ ) //if there is an appropriate learning resource format that suits the disability type
    analyse  $D_iF_i$ ;
else if ( $D_iF_i = 0$ ) //if an appropriate learning resource format that suits the disability type is not found
    return error message;
else {
    result =  $R_i$ ;
     $D_iF_i$ ;
    result;
}
return result;

```

Figure 42. Personalisation algorithm pseudo code for a student without disability

The implemented interface for a student without disabilities is presented in Figure 43.

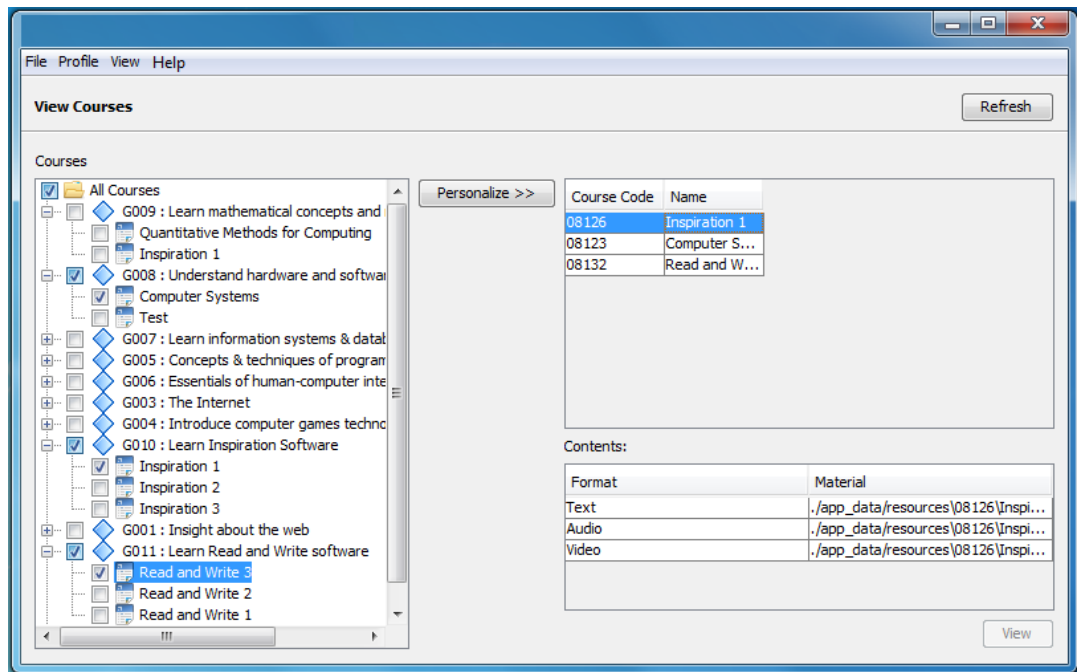


Figure 43. Interface showing personalisation for a student without disability

As can be seen in Figure 43, the student without disability is recommended learning resources that match their learning goals in all three formats of audio, text and video and this allows them the choice of selecting which format they wish to view.

5.8.2 Case Study on a Student with Multiple Disabilities

A great difficulty faced by e-learning systems is the personalisation of resources for a learner with multiple disabilities. ONTODAPS provides a mechanism for handling multiple disabilities. Let us consider a student with both a learning difficulty (e.g. dyslexia) and a visual disability (visual impairment) who requests a learning resource from ONTODAPS. ONTODAPS first enables the student to identify themselves based on their disability type and learning goals.

Once the information is received, ONTODAPS goes through two processes of producing the learning resource in an appropriate format. First, ONTODAPS goes through the resources in the system and the personalisation agent searches for learning

resources suitable for those with visual impairment and those suitable for those with dyslexia then the personalisation agent combines the resources to present materials that are suitable for both types of disabilities. These are then presented to the student as shown in Figure 44.

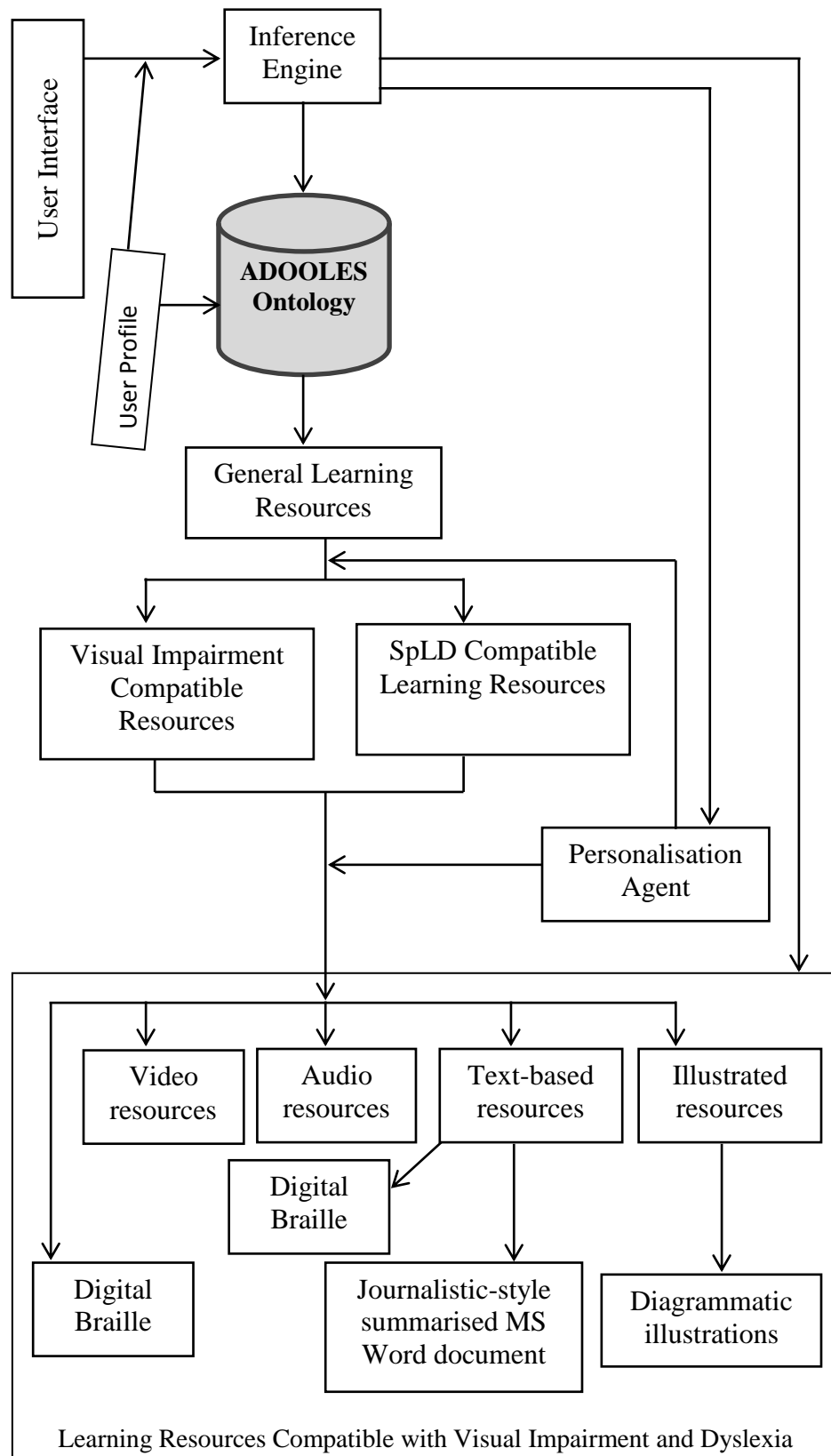


Figure 44. Personalisation for a student with multiple disabilities

Some processes on Figure 44 such as the user profile, learning resources and the personalisation agent have already been discussed. However, the personalisation agent was not discussed in much detail. We now focus our attention on how this agent accomplishes personalisation.

Let us consider the personalisation algorithm for the case of an individual who has two types of disabilities (multiple disabilities) which is blindness and dyslexia. A sample input and output data for the personalisation agent dealing with a case of dyslexia and blindness represented in Figure 45.

Input	<i>learning goals, disability</i> $\langle G_i D_i D_{dys}, G_i D_i D_{bli}, output\ trigger \rangle$
Output	<i>resource_format, learning resource</i> $(D_{dys}F_v, D_{dys}F_a, D_{dys}F_t, D_{bli}F_v, D_{bli}F_a, D_{bli}F_t, R_{dysbli});$

Figure 45. Input and output data in the personalisation agent for a student with multiple disabilities

Input: the input as seen in Figure 45 is information about the various disabilities the individual has. In this case, the individual has a multiple disability which consists of dyslexia and blindness. The input also receives an output trigger or iterator which initiates the process of presenting the personalised results.

Output: the output consists of learning resources in formats that are suitable for both dyslexia and blindness. If an audio lecture for Computer Systems is present but has no captions for instance, it is unsuitable for visual impairment, which may also be compounded by the fact that John Bull has dyslexia. Thus, the audio file will not be recommended. On the other hand, if the audio file contains captions and the video contains sound, such resources will be recommended. Thus the personalisation agent retrieves learning resources in formats common to both dyslexia and blindness as expressed below:

$$R_{dysbli} = R_{dys} \cap R_{bli} \text{-----} (2)$$

The pseudocode for the algorithm that provides the personalisation is in Figure 46. The personalisation agent having received the information about the disability type and learning goals goes through the available resources. It begins by analysing resources for each disability and where none is found for that disability, it infers that the individual probably does not have that disability and hence might have been an input error. It thus proceeds to analyse the learning resources of the other disability as shown in the pseudo code in Figure 46.

```

Fi = learning resource format {Fv= video, Fa= audio and Ft= text}
Di = type of disability {Ddys=dyslexia, Dbli=blindness or visual impairment}
Ri = learning resource {Rdys=resources suitable for dyslexia, Rbli= resources suitable for blindness}
Gi =learning goal
Input: learning goals, disability < Gi Di Ddys, Gi Di Dbli, output trigger>
Let Rdys be the learning resources suitable for a person with dyslexia
while (DdysFv != DdysFa != DdysFt && DbliFa != DbliFt != DbliFv)
if (DdysFi > 0) //if there is an appropriate learning resource format that suits the disability type

    analyze DdysFi;
else if (DdysFi = 0) //if an appropriate learning resource format that suits the disability type is not found

    return error message;
else {
    result= Rdys;
    DdysFi;
    result;
}
return result;
Repeat for DbliFi;
Output: resource_format, learning resource ( DdysFv, DdysFa, DdysFt, DbliFv, DbliFa, DbliFt,
Rdysbli)

```

Figure 46. Personalisation algorithm pseudo code for multiple disabilities

If resources are found that match both disabilities, it combines the resources and sorts out those that are suitable for both disabilities as earlier expressed in equation 2 above.

The resultant resources matching both blindness and dyslexia are thus recommended to the user in the formats specified by them; they can then access the resources.

5.8.3 Case Study on a Student with a Single Disability

The process for personalising resources for a student with a single disability is different from a case with multiple disabilities. This section will consider two examples of such cases, for a visually impaired student and for a student with dyslexia.

5.8.3.1 Case Study on a Student with Visual Impairment

Students with visual impairments could face a lot of difficulties accessing learning resources if care is not taken to provide information in an appropriate format. A visually impaired student such as one who is blind might be unable to see but could hear, so information could be presented in formats that make use of the sense of hearing and touch rather than visuals; such as presenting information in audio formats or Braille. Text-based information could still be converted to speech using screen readers.

Considering the ONTODAPS system, if a student with visual impairment visits ONTODAPS and requests a specific learning resource for a Computer Science course for instance; ONTODAPS asks them to identify themselves based on their needs which could be their disability needs, learning needs expressed through their learning goals and their preferences of the format of resources. This student first provides the information by entering their type of disability (visual impairment) and secondly, the student informs ONTODAPS of their learning goals which might be for instance to be able to demonstrate an understanding of hardware, then the system asks them to select their preference for the format of the resource which could be video, audio or text-based. Text-based resources could be documents such as Word, Excel, PowerPoint, PDF or HTML format. There could also be learning resources in digital Braille format. The audio format would be useful for a student with visual impairment who can listen to

the audio. It is also possible that a student with visual impairment may want to access a video learning resource due to the audio component.

The information supplied by the student is input into the system and in return, they receive the desired learning resources in formats appropriate for them. Figure 47 shows the information being received by the personalisation agent and the recommendations.

Input	<i>learning goals, disability</i> $\langle G_i D_i D_{vi}, output\ trigger \rangle$
Output	<i>resource_format, learning_resource</i> $(D_{vi}F_v, D_{vi}F_a, D_{vi}F_t, R_{vi});$

Figure 47. Input and output data in the personalisation agent for a student with visual impairment

Where

D_{vi} represents visual impairment

R_{vi} represents learning resources compatible with visual impairment

The process through which personalisation is accomplished for a student with visual impairment is shown in Figure 49.

Having gone through the process of providing their personal details which are stored in their profile, the system interacts with the ADOOLES ontology and searches through the general learning resources. The personalisation agent is then invoked and in collaboration with the inference engine sorts the learning resources and retrieves those that meet the learner's learning goals in their preferred format. In the case of a student with visual impairment, the resources presented will be audio and text-based resources but there is possibility of recommending other suitable formats where they exist such as digital Braille. In the case where video clips are present and the student needs such format, the video will contain an audio or text-based alternative.

The specific algorithm for accomplishing this personalisation which in a case of a single disability slightly differs from that of multiple disabilities is shown in Figure 48.

```

Initialisation
Let  $R_{bli}$  be the learning resources suitable for a person with visual impairment
while ( $D_{bli}F_v \neq D_{bli}F_a$  &&  $D_{bli}F_a \neq D_{bli}F_t$ )

if ( $D_{bli}F_i > 0$ ) //if there is an appropriate learning resource format that suits the disability type
    analyse  $D_{bli}F_i$ ;
else if ( $D_{bli}F_i = 0$ ) //if an appropriate learning resource format that suits the disability type is not found
    return error message;
else {
    result =  $R_{bli}$ ;
     $D_{bli}F_i$ ;
    result;
}
return result;

```

Figure 48. Personalisation algorithm pseudo code for visual impairment

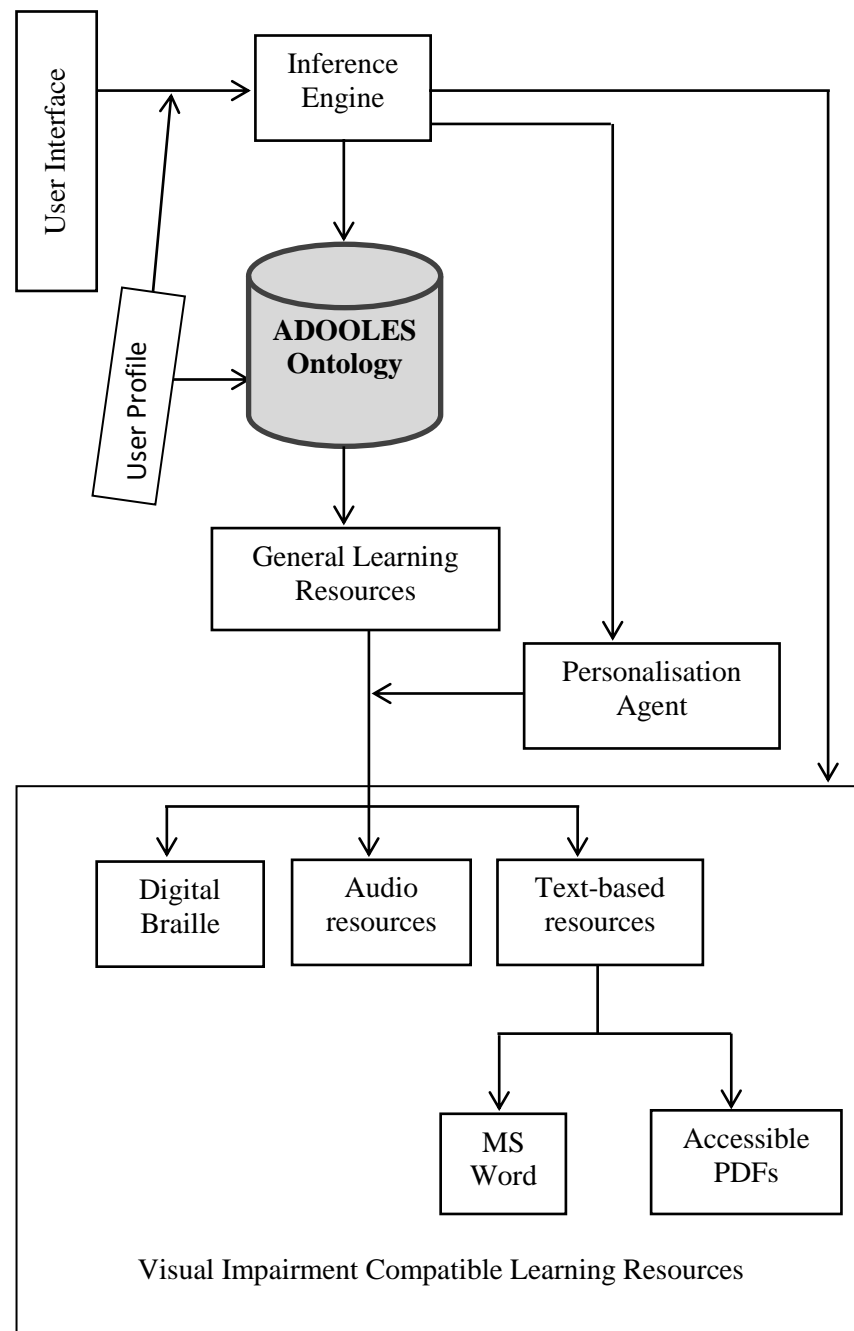


Figure 49. Personalisation process for a student with visual impairment

The user is thus recommended learning resources for the specific course that matches their learning goals and in a format that is suitable for their disability and their preferences as shown in Figure 49. In this case, text-based resources such as MS Word documents, accessible PDFs, audio resources and digital Braille is presented. The

student can then access the course in any of those formats. The implemented interface displaying such personalisation for a visually impaired individual is shown in Figure 50.

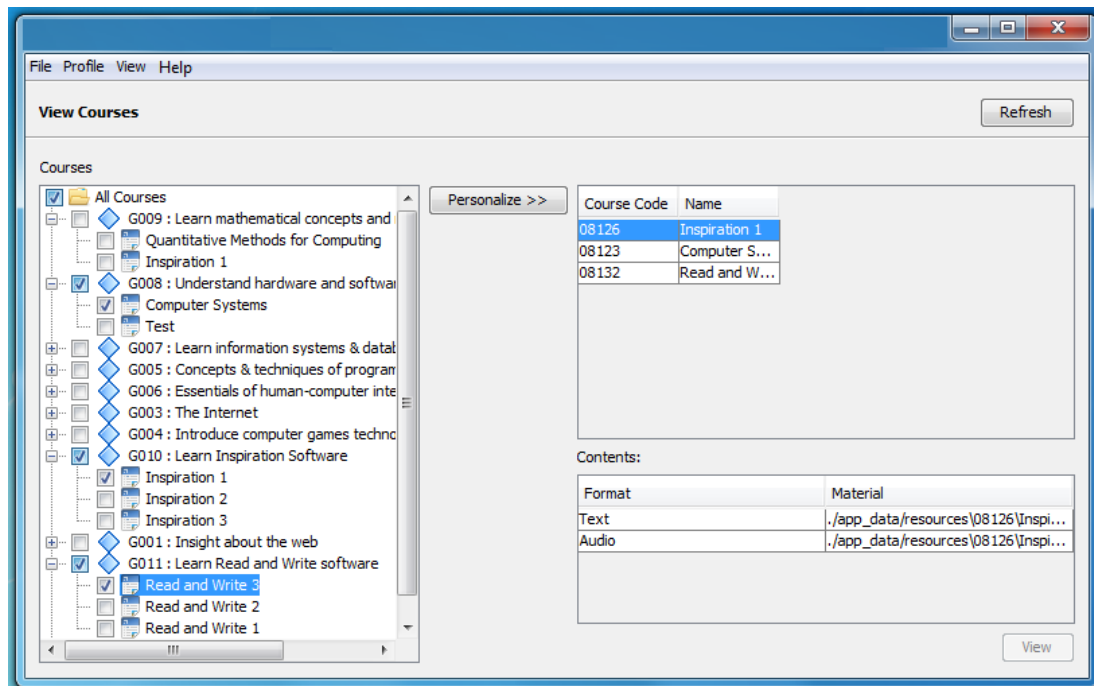


Figure 50. Interface showing personalisation for a student with visual impairment

A screen reader could be used in combination with the text-based resources; therefore, it is important for the e-learning system to have an inbuilt screen reader which will convert text into speech for a student with complete blindness. However, for a student with low vision who has some sight, the text-based resource could be presented in large fonts that might be visible to them or could be read with a screen magnifier.

5.8.3.2 Case Study on a Student with Dyslexia

A student with dyslexia who has poor visual memory may take a longer time to develop their reading skills and still present with some difficulties understanding words. Such a student could interact with ONTODAPS through the user interface on their computer and request lecture notes on the forthcoming lecture which has been uploaded by a lecturer prior to the lecture to enable them access the learning resource before the session in order to read through and understand. When the student accesses the user

interface, ONTODAPS asks them to identify them self, based on their disability and learning goals as well as the format in which the learning resource will be presented to them as in the other cases already seen.

The student might identify them self as having severe dyslexia and will need to access a summary of the learning resource with possible schematic representations of difficult concepts within that lecture. Just like the case for a visually impaired student, ONTODAPS personalisation agent goes through the resources and presents them with learning resources suitable for an individual with dyslexia such as video, audio, text-based and illustrated resources as shown in Figure 51.

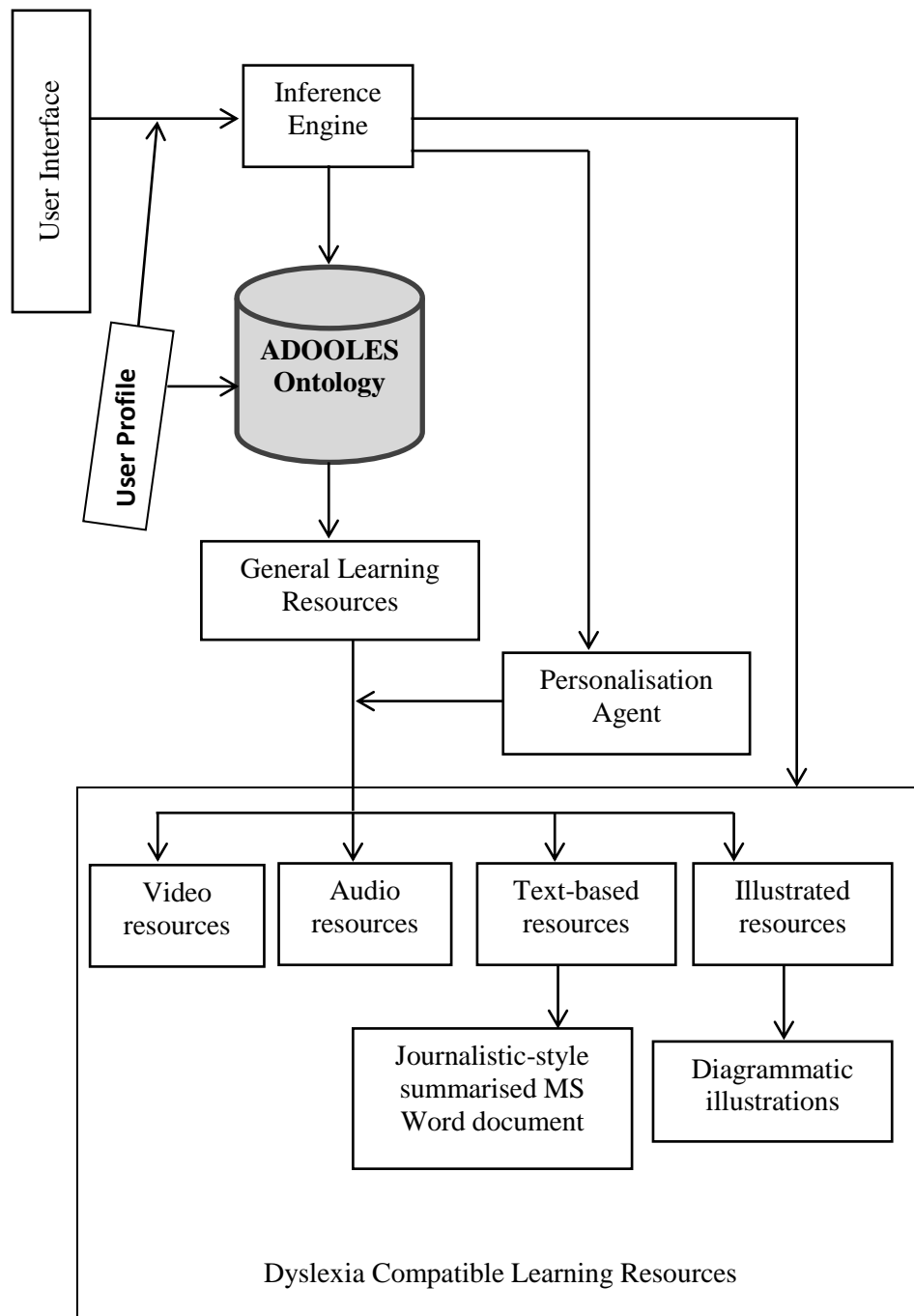


Figure 51. Personalisation process for a student with dyslexia

The text-based resources are presented in a format that is easy to understand, given that the student may have some reading problems and general problems understanding the document. Illustrated resources consist of diagrammatic illustrations which facilitates comprehension of the information being conveyed.

Just like in the other cases already discussed, personal information about the user contained in their profile is fired to the personalisation agent which in return provides a recommendation in the form of an output as shown in Figure 52.

Input	<i>learning goals, disability</i> $\langle D_i, D_{dys}, output\ trigger \rangle$
Output	<i>resource_format, learning resource</i> $(D_{dys}F_v, D_{dys}F_a, D_{dys}F_t, R_{dys});$

Figure 52. Input and output data in the personalisation agent for a student with dyslexia

Where

D_{dys} represents visual impairment

R_{dys} represents learning resources compatible with visual impairment

The personalisation agent then interacts with the learning resources through queries and using some algorithms as shown in Figure 53.

```

Initialisation
Let  $R_{dys}$  be the learning resources suitable for a person with dyslexia
while ( $D_{dys}F_v \neq D_{dys}F_a \ \&\& \ D_{dys}F_a \neq D_{dys}F_t$ )
if ( $D_{dys}F_i > 0$ ) //if there is an appropriate learning resource format that suits the disability type
    analyse  $D_{dys}F_i$ ;
else if ( $D_{dys}F_i = 0$ ) //if an appropriate learning resource format that suits the disability type is not found
    return error message;
else {
    result =  $R_{dys}$ ;
     $D_{dys}F_i$ ;
    result;
}
return result;

```

Figure 53. Personalisation algorithm pseudo code for dyslexia

As shown in Figure 53, the individual is recommended the learning course in a format that is suitable for comprehension by an individual with dyslexia. The personalisation agent goes through all the learning resources and if it finds no available resources, it prompts the user through an error message to verify the information input. Where the information is correct, the agent will now sort out the resources that are suitable with the degree of that disability and then recommend them to the learner. Where the individual

has severe dyslexia, more illustrations and simplifications will be used. For instance, text-based materials will need to be summarised and written in a style that the user can readily find the key information not far down the document, but at the beginning as is done in journalistic writings where a summary is found at the top and then expounded later on.

5.9 Summary

The problem of most e-learning systems being unable to provide adequate personalisation for users, particularly those with disabilities had been earlier noted in this thesis. This chapter has introduced ONTODAPS' solution to this problem. ONTODAPS through its personalisation agent, inference engine and ontologies intercommunicate to bring about effective personalisation for the learner. The personalisation agent accomplishes this through specific algorithms depending on the type of disability. It is able to retrieve the correct learning resources due to their semantic annotations and can retrieve them with specific queries.

The following chapter will experimentally evaluate the ONTODAPS model through the visual interface by using lecturers (heuristic evaluation) and students with disabilities (user evaluation) to measure the performance of ONTODAPS in terms of precision, recall and F-score in addition to the other variables that were discussed at the beginning of this chapter.

Chapter 6: Evaluation of the ONTODAPS Model

6.1 Overview

Chapter 5 presented some case studies using the ONTODAPS model to provide personalisation for students, explaining how personalisation is accomplished.

In this chapter, the ONTODAPS visual interface will be evaluated by experts (heuristic evaluation) and students (user evaluation). In Section 5.2 of Chapter 5, the evaluation strategy was presented including some limitations from this evaluation. Both heuristic evaluation and user evaluation will help to find usability problems with the visual interface that will inform decision on how to improve the system and recommendations on designing inclusive learning environments. The results of the evaluation will also be presented. The user evaluation results for both students with disabilities and students without disabilities will be compared and used to judge the usability and effectiveness of ONTODAPS as an e-learning system for both groups of students.

6.2 Results of Evaluation with Experts (Heuristic Evaluation)

The ONTODAPS visual interface was evaluated heuristically by 8 lecturers from the University of Hull and 2 lecturers from the East Riding College, the latter taught on the University of Hull Foundation Degree (FdSc) with approved status for this purpose; all were either experienced in e-learning, education or human-computer interaction (HCI). Some of the evaluators had prior experience of carrying out heuristic evaluation.

The aim of the evaluation was to find any usability problems that exist within ONTODAPS. Prior to carrying out this evaluation, a pilot heuristic evaluation was carried out using three lecturers in computer science.

The evaluators (N=10) were asked to interact with the ONTODAPS visual interface at least twice before carrying out specific tasks. Heuristic evaluators interacted with the interface as administrators and as students in order to understand the complete functions of the system. Prior to this, they accessed the ONTODAPS tutorial as students and administrators in any format of their choice (text, video, audio). The tutorial gave guidance on carrying out tasks on the system and demonstrated the functions of the system.

The evaluators then carried out the specified tasks (see appendix G for specified tasks), whilst the researcher watched on a screen and also recorded the task completion time, number of errors made and the accuracy of the task completion. The evaluators also noted any problems they encountered whilst carrying out the tasks.

After completing the tasks, the evaluators then filled an evaluation form which evaluates the ONTODAPS visual interface (see appendix F for evaluation) based on Nielsen's (1994) *interface design heuristics*, Quinn's (1996) *educational design heuristics* and Squires and Preece's (1999) *learning with software heuristics*. The evaluators were instructed to rate how the ONTODAPS visual interface meets each heuristic by scoring this on a scale of 10 with the lowest value being 0. In the case where evaluators found a usability problem with the system for each of the heuristic, they were then asked to state the severity of the usability problem according to the scale in Table 10. The results from the questionnaire were collected, analysed and presented.

6.2.1 Preference of Tutorial Format

The results obtained from the heuristic evaluation were analysed using SPSS while Microsoft Excel was used to generate some of the charts. As shown in Figure 54, 40% of the evaluators accessed the tutorial in text format, 40% in video format, and 20% in both text and video format while none accessed the audio tutorial.

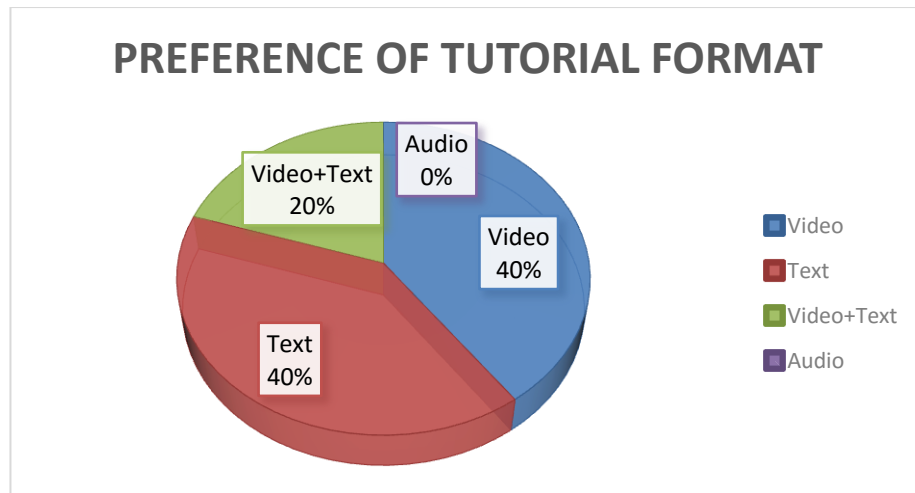


Figure 54. Heuristic evaluators' preference of tutorial format

The preference of tutorial format for heuristic evaluators might be related to their learning styles. The video tutorial contained a demonstration of the functions of ONTODAPS and included subtitles which could be useful for those with hearing impairment. Also, the video could be paused or stopped at any time. Some of the evaluators preferred to interact with ONTODAPS whilst watching and pausing the video tutorial to attempt some tasks as demonstrated in the video. The same behaviour was observed for some evaluators who accessed the tutorial in Microsoft Word format as they read portions of the tutorial and then proceeded to attempt some tasks.

6.2.2 Usability of ONTODAPS

Heuristic evaluators were given an evaluation form containing the heuristics and how ONTODAPS should meet those heuristics. They were then required to assess how well the system met those heuristics and to record any usability violations against a severity scale. The results of heuristic evaluators' interaction with ONTODAPS whilst performing the specified tasks are presented in Table 7.

Table 7. Task completion time, accuracy and errors made by heuristic evaluators

	Time taken to accomplish tasks (minutes)	Number of correct tasks	Number of partial tasks	Number of failed tasks	Number of errors
N Valid	10	10	10	10	10
Missing	0	0	0	0	0
Mean	8.7000	4.4000	0.6000	0.0000	1.4000
Std. Deviation	3.62246	1.57762	1.57762	0.00000	1.71270
Variance	13.122	2.489	2.489	0.000	2.933

The task times were measured in minutes. The tasks and their descriptions were as shown in Table 8.

Table 8. Heuristic evaluation tasks and their descriptions

Task	Task Description
Task 1	Register into the system as an administrator then register a new student into the system and assign a learning goal to them, selecting their disability type as visual impairment and severity as moderate.
Task 2	Add a new course and upload learning resources for that course in three formats: text, audio and video.
Task 3	Create a new learning goal for the course you just created, assign that learning goal to moderate visual impairment and to that course.
Task 4	For the course you just created, click to view the video, audio and text.
Task 5	Change the email address of the user you registered, and then change your own email address.

6.2.2.1 Accuracy of task completion (effectiveness)

The task accuracy was recorded as either correct, which means the evaluator completed the task as required; partial where the evaluator carried out the task but did not complete it; and failure where the evaluator could not do the task at all.

As shown in Table 7, when translated into percentages, the task completion was 88% correct, 12% partial and 0% failed tasks. Some partial task examples for Task 2

included adding a new course and uploading learning resources in one format only instead of in all three formats as instructed. The results suggest that the ONTODAPS visual interface enables lecturers to easily upload and manage courses and learners, helping to minimise errors.

6.2.2.2 Task completion time (efficiency)

Whilst the task accuracy was being recorded, the time taken to accomplish these tasks was also noted. The mean time taken by the evaluators to accomplish the five tasks was 8.7 minutes as shown in Table 8 which implies that the average time taken to carry out each task was 1.7 minutes.

The task completion time could be an important factor in determining whether the lecturers who use this system would continue using it. If it takes a very long time to do basic tasks, they might prefer using a different system.

6.2.2.3 Number of errors made

The number of errors made by the evaluators while performing the specified tasks was also recorded. The errors included double clicking to open a learning resource rather than clicking a button to open the resource, using the wrong username and password to login which led to the system displaying error messages, just to name a few.

The mean number of errors for all tasks was 1.4. This implies that the system was easy to use and helped prevent errors. Were evaluators not able to understand how to use the system due to its complex architecture, they would have made more errors. On the contrary, the architecture was simple enough and hence they could understand it and thus made very few errors.

6.2.3 Heuristic Score

The ratings of the ONTODAPS visual interface on a scale of 10 by the evaluators for each heuristic are presented in Table 9. The source from where the heuristics are derived are shown in appendix G.

Table 9. Results of the heuristic evaluation of the ONTODAPS visual interface

	N	Mean	Std. Deviation	Variance
Ensures visibility of system status	10	6.8000	1.75119	3.067
Provides match between the system and the real world	10	6.9000	1.96921	3.878
Flexible enough to provide the user enough control and freedom	10	8.4000	1.34990	1.822
Is consistent and follows common operating system standards	10	8.0000	1.41421	2.000
Prevents errors	10	7.0000	2.21108	4.889
Supports recognition rather than recall	10	7.4000	1.89737	3.600
Supports flexibility and efficiency of use	10	7.4000	2.17051	4.711
Uses aesthetic and minimalist design	10	7.1000	1.96921	3.878
Helps users recognise, diagnose and recover from errors	10	6.9000	2.76687	7.656
Provides help and documentation	10	8.2000	2.14994	4.622
Has clear goals and objectives	10	6.4000	2.67499	7.156
Context is meaningful to domain and learner	10	7.4000	1.64655	2.711
Content clearly and multiply represented and multiply navigable	10	7.5000	1.58114	2.500
Provides navigational fidelity	10	7.1000	1.66333	2.767
Provides appropriate levels of learner control	10	8.2000	1.39841	1.956
Supports personally significant approaches to learning	10	8.2000	1.87380	3.511
Valid N (listwise)	10			

These results reveal the strengths of ONTODAPS visual interface as evaluated by experts. The interface scored very well (mean of above 8.0) for its flexibility, in which case the evaluators agreed that it is flexible enough to provide the user enough control and freedom. The results in Table 11 seem to corroborate this as the evaluators could only find minor usability problems with its flexibility.

ONTODAPS was also seen to be consistent in following common operating system standards with the menus following platform standards. Again, results from Table 11 corroborate this as only minor usability problems were recorded.

ONTODAPS also provided help and documentation with a help menu which shows users how to accomplish basic tasks. Although the tutorial was presented in text, video and audio formats, the help provided was only available in text format, thus as seen in Table 11, a major usability problem was recorded. The ability to access other formats of the help and documentation from the system would have been more inclusive of all learners and also suitable for all learning styles.

ONTODAPS was also rated well in its ability to provide appropriate levels of learner control such as allowing learners to self-direct their learning through personalising learning resources and allowing them to choose which resources to access, thus giving them a sense of ownership and control for which no usability problem was found as seen in Table 11. Similarly, only cosmetic problems were found with its ability to support personally significant approaches to learning such as considering different learning styles and presenting materials in alternative formats suitable for various disabilities.

ONTODAPS, however, had some major usability problems such as with ensuring system visibility status where it scored 6.8 and 6.4 for clear goals and objectives. The

system needs to be improved on its ability to keep the user informed about what is going on, through appropriate and timely feedback, allowing users to move on to other tasks. The main problem was that while a learning resource was being accessed, users could not proceed to other tasks without closing the resource.

The number of minor and major usability problems found with the visual interface suggests that the interface needs to be improved before it could be released for real use. The severity of the usability problems encountered was recorded as shown in Table 10. These problems included cosmetic, minor, major and catastrophic problems in addition to some of the problems being judged as not being a usability problem.

Table 10. Severity scale for usability problems

Severity	Description
0	I don't agree that this is a usability problem at all
1	Cosmetic problem only; need not be fixed unless extra time is available
2	Minor usability problem; fixing this should be given low priority
3	Major usability problem; important to fix; so should be given a high priority
4	Usability catastrophe; imperative to fix before this product is released

The severity of the usability problems found for each of the heuristics was recorded by each evaluator. Each evaluator judged the interface based on the evaluation form and their interaction experience with the system.

Whilst cosmetic and minor usability problems are given lower priority for fixing them, major and catastrophic usability problems are given very high priority and are usually imperative to fix before releasing the product for use by its target users.

6.2.3.1 Usability Violations

The results of the usability violations for each heuristic as recorded by the evaluators are presented in Table 11. The X's in the table show the usability violations identified by

the evaluators, for each heuristic and the severity of such violations earlier presented in Table 10.

Table 11. The severity of usability violations (X) in the ONTODAPS visual interface

No	Heuristic	Severity of usability problem				
		0	1	2	3	4
1	ONTODAPS ensures visibility of system status	X	X	X	X	
2	ONTODAPS provides a match between the system and the real world		X	X	X	
3	ONTODAPS is flexible enough to provide the user enough control and freedom	X	X	X		
4	ONTODAPS is consistent and follows common operating system standards	X	X	X		
5	ONTODAPS prevents errors		X	X	X	
6	ONTODAPS supports recognition rather than recall	X	X	X		
7	ONTODAPS supports flexibility and efficiency of use	X	X		X	
8	ONTODAPS uses aesthetic and minimalist design	X	X	X	X	
9	ONTODAPS helps users recognise, diagnose and recover from errors	X	X		X	
10	ONTODAPS provides help and documentation	X	X		X	
11	ONTODAPS has clear goals and objectives	X	X		X	
12	ONTODAPS context is meaningful to domain and learner	X				
13	ONTODAPS content clearly and multiply represented and multiply navigable	X	X			
14	ONTODAPS provides navigational fidelity	X	X			
15	ONTODAPS provides appropriate levels of learner control	X				
16	ONTODAPS supports personally significant approaches to learning	X	X			

Statistically, the usability problems found in the system are represented in Table 12.

Table 12. Statistical analysis of usability problems

	Not a usability problem	Cosmetic usability problem	Minor usability problem	Major usability problem	Usability catastrophe
N Valid	10	10	10	10	10
Missing	0	0	0	0	0
Mean	2.6000	2.0000	2.7000	1.2000	0.0000
Std. Deviation	4.08792	2.70801	2.71006	2.20101	0.00000
Variance	16.711	7.333	7.344	4.844	0.000
Sum	26.00	20.00	27.00	12.00	0.00

The sum for each usability problem found is shown in Table 12. The number of major and minor usability problems encountered suggests that the system needs to be improved before it could be released for use. In addition to the evaluation, the evaluators gave some comments and suggestions that could help improve the system's usability.

6.2.4 Limitations of the system and suggestions for improvement

Evaluators recommended an improvement of the menus to make things more evident for the users, so that they can know where to find things.

When information has been changed on the system, some evaluators recommended that the system should tell the user so that they can save the changes. A suggested implementation will be a pop up message to prompt users to save the information.

Whilst the tutorial was presented in audio, video and text formats and could be accessed from the computer, only a text-based help was available in the system. Some of the evaluators therefore recommended the incorporation of an audio and/or visual help accessible from the Help menu.

Some of the keyboard only functions were not activated in the system. Some evaluators recommended an activation of these functions. This will be very helpful for users who

rely solely on keyboard input rather than having to use the mouse. This will be particularly very helpful for some users with upper limbs mobility difficulty.

Whilst ONTODAPS could be used to effectively personalise learning resources for students and could allow lecturers to also easily upload and manage courses, one of the evaluators who is a lecturer in digital media and an expert in Web 2.0 recommended that a web-based implementation will be a better option rather than a Java implementation. Web-based ONTODAPS could enable more user control and facilitate implementation of key functionalities.

6.2.5 Conclusions from Evaluation with Experts

The results of ONTODAPS heuristic evaluation suggest an overall good interface to facilitate various tasks. Nevertheless, some usability problems were found with the interface, suggesting that it needs to be improved before this system could be released for use in a large scale.

6.3 Results of Evaluation with Learners

The ONTODAPS evaluation strategy was discussed in Section 5.2 of Chapter 5, thus the procedure will not be repeated in this section. However, before carrying out the experimental evaluation with students, Ethical Clearances were obtained from the Department of Computer Science, University of Hull and from the University of Ottawa Ethics Committee in order to carry out the research. Once these were obtained, the Student Academic Success Service (SASS) and the Centre for Students with Disabilities (CSD) were contacted and accepted to send emails to all students registered as having disabilities (Appendix B). In addition to the email, CSD also put up a poster that was prepared by the researcher (Appendix D), on their notice board and included a "blurb" about the research in their newsletter and on their Facebook page. The researcher also obtained permission from the Community Life Service to place posters on various

boards around the campus for recruitment purposes. For the purpose of the experiments, only those who had dyslexia, low vision and/or hearing impairment were chosen to participate in this study. Dyslexia was chosen as it is the most common disability amongst higher education students (Dunn, 2003a, Snowling, 2001). As earlier discussed in Chapter 2, Kelly and Smith (2008) assert that students with visual impairment such as those using screen readers are more disadvantaged than those with other disabilities. Hearing impairment on the other hand, affect students in a different way and the format of learning materials could determine if students with such impairment can access learning materials or not. Thus, the above three disabilities or a combination of them will be representative of the disability types encountered in education and will thus be appropriate to use in the experiments. No compensation was offered to participants.

A laptop computer was setup in a room, away from distractions and interference. Participants were asked to sign a consent form (Appendix A) and then access a tutorial on ONTODAPS in either of three formats (audio, text, and video) and during the evaluation, participants accessed the formats of their choice as discussed in Section 5.2.

The results from the evaluation of ONTODAPS will be divided into *Demographics* where the disability type, gender, age group and computer proficiency of the learners will be recorded, *Performance*, *Usability*, *Attitude* and *Interactivity*.

6.3.1 Demographics of Participants

Amongst other questions asked in the questionnaire, learners were asked about their disability type, gender, age group and computer proficiency.

6.3.1.1 Distribution of Participants by Disability, Gender and Age

The demographic statistics collected from the participants related to their disability type(s), gender and age are presented in Table 13.

Table 13: Distribution of Participants by Disability, Gender and Age

Disability Type	Gender (n=18)		Age Group (n=18)		
	Males	Females	17-20	21-25	>25
Dyslexia	6	5	5	4	2
Hearing Impairment	0	3	0	0	3
Visual Impairment	0	2	1	1	0
Hearing Impairment+Dyslexia	0	2	0	2	0
Total	6	12	6	7	5

There were more female participants (~67%) than males, with about 39% of the participants belonging to the 21-25 age group. 61% of the participants had dyslexia, which seems to confirm the assertion by Dunn (2003b) and Snowling (2001) that dyslexia is the most common disability amongst students in higher education. However, this needs to be confirmed in a larger scale sampling. Only 2 students with multiple disabilities (Hearing impairment and dyslexia) participated in this study, which is a limitation of this study as identified in Section 5.2.6.

In an earlier evaluation with students at the university of Hull in January 2012, it was also noticed that some students presented with multiple disabilities which were a combination of two or more disabilities such as a combination of specific learning difficulty and mobility difficulty; a combination of mobility difficulty, specific learning difficulty and visual impairment; a combination of hearing impairment and specific learning difficulty and a combination of specific learning difficulty, visual impairment and hearing impairment. Such cases of multiple disabilities pose a great challenge on how to provide personalisation but participants with such disabilities from our interaction expected to find the learning resources in all three formats so that they could choose which format was most suitable for them.

6.3.1.2 Distribution of Participants by Disability and Computer Proficiency

The statistics collected from the participants regarding their disability type in relation to their computer proficiency is presented in Table 14.

Table 14: Distribution of Participants by Disability and Computer Proficiency

Disability Type	Computer Proficiency (n=18)		
	Novice	Intermediate	Advanced
Dyslexia	3	4	4
Hearing Impairment	1	1	1
Visual Impairment	0	0	2
Hearing Impairment+Dyslexia	0	1	1

Amongst the participants, 44% reported that they had advanced knowledge of computers with those who presented with dyslexia forming the majority of the advanced computer users. This is not surprising as they were the majority in the study. Coincidentally, there were also more students with dyslexia who reported that they were novice users of computers. Also, there were more students with dyslexia who were intermediate computer users. The two visually impaired students were advanced computer users.

6.3.2 Performance of ONTODAPS

As discussed in Chapter 5 (Section 5.2.4), the performance of ONTODAPS was determined through measuring the precision, recall and F-values based on the number of learning materials that were retrieved by the participants with or without ONTODAPS. The importance of precision, recall and F-values was also discussed in that section. In the baseline test (without software intervention), participants went through learning materials in a repository and retrieved materials on specific subjects. In Test 1, they were asked to retrieve learning materials that enabled them to improve their knowledge on Biology; in Test 2, they retrieved learning materials that enabled them to learn the software Read & Write; while in Test 3, they retrieved learning materials that enabled

them to learn the software Inspiration. The same Tests were done in the Intervention phase but this time, using ONTODAPS to retrieve the learning materials. The number of true positives (TP), false positives (FP) and false negatives (FN) were recorded and used to calculate the precision, recall and F-score as explained in Section 5.2.4 of Chapter 5.

6.3.2.1 Baseline Test

The main purpose of having the baseline test was to establish a basis for evaluating the performance of ONTODAPS in the intervention test. By having users manually retrieve the learning materials in the baseline phase, the performance of ONTODAPS could later be measured compared to the baseline phase. The values for precision and recall range from 0 to 1 and are expressed as fractions. Based on the formula for calculating precision and recall in Section 5.2.4, a perfect score of 1 for precision is achieved when there is no false positive (that is, all the materials retrieved are relevant), while a perfect score of 1 for recall is achieved when there is no false negative (all relevant materials being retrieved and no relevant materials were left out). As will be seen from the baseline results, the students did not achieve a perfect score for precision and recall as some relevant materials were not retrieved. Some of the materials retrieved might have been irrelevant. The results of retrieving the learning materials in the baseline phase are presented below.

Test 1: Improving Knowledge on Biology

The results from manually retrieving learning materials to improve knowledge on Biology are presented in Table 15.

Table 15: Results of Baseline Test 1, Improving Knowledge on Biology

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.5414	0.5535	0.5474	0.11042	0.10284

According to Costello (2012), recall values over 0.6 and precision values close to 0.7 are relevant. The values obtained from manually searching the repository for learning materials that would help improve the participants' knowledge on Biology were thus not very effective.

Test 2: Learn the Software Read & Write

The results from manually retrieving learning materials that enable learners to learn the software Read & Write are presented in Table 16.

Table 16: Results of Baseline Test 2, Learn the Software Read & Write

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.6018	0.5797	0.5905	0.12940	0.14604

As with Test 1, the results from Test 2 shows that it was less effective manually retrieving learning materials that enabled learners to improve their knowledge on the software Read & Write.

Test 3: Learn the Software Inspiration

The results from manually retrieving learning materials that enable learners to learn the software Inspiration are presented in Table 17.

Table 17: Results of Baseline Test 3, Learn the Software Inspiration

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.5489	0.5213	0.5347	0.16753	0.13756

The results from this test also goes further to confirm that manually retrieving learning materials from the repository is less effective as the results were not very relevant.

6.3.2.2 Intervention Test

The intervention tests enabled the performance of ONTODAPS to be compared with the baseline tests. The precision, recall and F-values were also calculated same as in the baseline phase. Mean values were used as discussed in Chapter 5. The results of retrieving learning materials on specific subjects using ONTODAPS are presented below.

Intervention Test 1: Improving Knowledge on Biology

The results from retrieving learning materials with ONTODAPS to improve knowledge on Biology are presented in Table 18.

Table 18 : Results of Intervention Test 1, Improving Knowledge on Biology

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.8259	0.8533	0.8394	0.05927	0.07217

Unlike in the baseline phase where the results from manually retrieving learning materials from the repository were not relevant, both the precision and recall values in the Intervention test where ONTODAPS was used are relevant. The precision and recall values increased with the use of ONTODAPS to retrieve the learning resources. Thus, it was easier and more effective for participants to retrieve the correct formats of learning materials for each learning goal using ONTODAPS. The F-value further confirms this.

Intervention Test 2: Learn the Software Read & Write

The results from retrieving learning materials with ONTODAPS that enable learners to learn the software Read & Write are presented in Table 19.

Table 19: Results of Intervention Test 2, Learn the Software Read & Write

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.8726	0.8136	0.8421	0.07288	0.08800

Similar to Test 1 of the Intervention phase, participants were able to retrieve the correct learning materials in the appropriate format using ONTODAPS. The precision and recall values are similar to those in Test 1. Thus, ONTODAPS appears to facilitate the retrieval of specific learning materials in the correct format as shown in the Case Studies in Chapter 5.

Intervention Test 3: Learn the Software Inspiration

The results from retrieving learning materials with ONTODAPS that enable learners to learn the software Inspiration are presented in Table 20.

Table 20: Results of Intervention Test 3, Learn the Software Inspiration

N	Mean Precision	Mean Recall	Mean F	Std. Dev. Precision	Std. Dev. Recall
18	0.8446	0.7731	0.8073	0.03927	0.19655

In the final test of the Intervention phase, ONTODAPS was able to retrieve learning materials with a similar precision value but the recall value dropped. Nevertheless, the F-value shows that the values are similar to those of Test 1 and 2.

It could be seen from the above results that the precision, recall and F-values increase as one moves from the baseline phase to the intervention phase. Thus, it is better to retrieve specific learning materials in the appropriate format using ONTODAPS than to do this manually. When the users retrieved the materials manually in the baseline test, they missed out on retrieving some of the relevant materials, hence they could not

obtain a perfect score of 1. With ONTODAPS however, they were able to retrieve more relevant results. An imperfect score in the baseline phase could also arise in the event that some learning materials are not correctly tagged.

6.3.3 Usability of ONTODAPS

The usability of the ONTODAPS system was measured by considering its *learnability*, *efficiency*, *memorability*, *errors* and *satisfaction* in accordance with Nielsen (2012). Learnability refers to how easy it is for users to accomplish basic tasks the first time they encounter the system. Efficiency refers to how quickly users can perform tasks once they have learned to use ONTODAPS after interacting with it. Memorability measures how easy it would be for users to re-establish proficiency with ONTODAPS if they were to return to it after a period of not using it.

6.3.3.1 Learnability

The learnability results are presented in Table 21.

Table 21: ONTODAPS Learnability results

N	Mean	Std. Deviation	Std. Error Mean
18	7.8000	1.21350	0.23065

6.3.3.2 Efficiency

The efficiency of ONTODAPS was measured by asking users to perform specific tasks and the time taken to carry out those tasks was recorded in minutes. The results are shown in Table 22.

Table 22: ONTODAPS Efficiency results

N	Mean	Std. Deviation	Std. Error Mean
18	5.2000	0.45475	0.08665

On average, participants took about 5 minutes to accomplish the tasks that were set for them to register on the system, select specific learning goals and retrieve specific learning materials.

6.3.3.3 Memorability

Memorability was measured at the end by asking users some questions to test their memory on how to perform some basic tasks using ONTODAPS and then scoring each question on 2.5 with a maximum cumulative score of 10. The memorability results are presented in Table 23.

Table 23: ONTODAPS memorability scores

N	Mean	Std. Deviation	Std. Error Mean
18	8.8540	1.16560	0.38506

On a scale of 10, the mean memorability score was 8.85. This suggests that participants easily became proficient at using ONTODAPS and could remember the functions of the system. Thus, the simplicity of the design means that learners will be able to quickly re-establish proficiency after a period of not using the system.

6.3.3.4 Errors

This refers to the number of errors users made during interaction with ONTODAPS and the severity of such errors. While users were performing the assigned tasks, the errors they made were recorded. The results from the analysis of the errors for both groups are shown in Table 24.

Table 24: Number of errors made by students

N	Mean	Std. Deviation	Std. Error Mean
18	1.0501	1.04220	0.18340

Whilst performing the tasks of registering on the system, selecting learning goals and personalising learning materials, participants made an average of one error, which is very good. This shows that the design is simple enough to be understood although it is able to perform its function of providing learners with the correct learning materials based on their learning goals and disability type.

6.3.3.5 Satisfaction

Having interacted with ONTODAPS and carried out the tasks, amongst the questions in the questionnaire, users were asked to rate their satisfaction with the ONTODAPS visual interface. Satisfaction was measured through how effective participants viewed the system. The results are presented in Table 25.

Table 25: Students' overall satisfaction with ONTODAPS

Poor	Fair	Satisfactory	Very Good	Excellent	Std Dev	Std Error
0	1	12	5	0	0.2363	0.0557

Most of the participants were satisfied with ONTODAPS, having interacted with the visual interface and accomplished various tasks.

6.3.4 Attitude towards ONTODAPS

The attitude towards ONTODAPS was measured by considering various emotional states of the participants such as confusion and interest.

6.3.4.1 Confusion

In measuring confusion, participants were asked to rate how confusing they found ONTODAPS to be. The results are presented in Table 26.

Table 26: Participants' reported confusion with ONTODAPS

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
8	8	0	2	0	0.2692	0.0635

The majority of participants did not find ONTODAPS confusing. However, of the 18 participants, 2 found ONTODAPS confusing to them.

6.3.4.2 Interest

The interest of the participants was measured by considering if participants found ONTODAPS beneficial to them, whether the system was relevant to their learning needs, could aid their learning experience and if the participants would use the functionality again if it were incorporated into another learning environment.

The results of asking participants if they found using ONTODAPS beneficial to them are presented in Table 27.

Table 27: Benefits of using ONTODAPS

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	1	3	5	9	0.3189	0.0752

50% of the participants strongly agreed that ONTODAPS was beneficial to them. They found that it could facilitate search and retrieval of learning materials and could also provide them with the correct format of learning materials. Only 1 participant did not find ONTODAPS beneficial.

The results of asking the participants whether the materials retrieved using ONTODAPS were relevant to their learning needs are presented in Table 28.

Table 28 : Relevance of materials retrieved with ONTODAPS

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	0	0	12	6	0.1940	0.0457

All the participants found that ONTODAPS returned the correct learning materials which were suitable to their learning needs and compatible with their disability type. This is reflected in the precision and recall values in the Intervention phase compared to the baseline phase which shows that it was more difficult to find the correct learning materials manually.

The results obtained from asking participants if using ONTODAPS aided their learning experience is found in Table 29.

Table 29: Ability of ONTODAPS to aid learning experience

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	1	3	10	4	0.3117	0.0735

The participants generally found that ONTODAPS aided their learning experience while 1 participant disagreed.

The results of asking participants if they would use ONTODAPS again in the event that its functionality was incorporated into another LMS/VLE are presented in Table 30.

Table 30: Participants' willingness to use ONTODAPS again

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	0	0	15	3	0.1534	0.0362

All the participants in this study expressed their willingness to use ONTODAPS again if it were offered as a functionality in an existing learning environment. They found it beneficial to have learning materials in various formats that are compatible to them and aids their learning experience. By including such functionality in a learning environment, learners can readily find specific learning materials and can get the learning environment to adapt to their special and educational needs.

6.3.5 Interactivity of ONTODAPS

The component of interactivity that was measured was consistency. Specifically, participants were asked about the consistency of the font and text size throughout the ONTODAPS environment as well as the consistency of the presentation. Their results are presented in Table 31.

Table 31: ONTODAPS font consistency

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	0	0	12	6	0.1940	0.0457

The results show that the font used in the visual interface of ONTODAPS was consistent throughout as confirmed by all the participants.

Participants were asked if the text size was consistent throughout the ONTODAPS environment. The results are presented in Table 32.

Table 32: Consistency of text size in the ONTODAPS environment

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	0	0	12	6	0.1940	0.0457

Similar to the font consistency, all the participants found the text size to be consistent throughout the ONTODAPS environment.

Participants were asked if the presentation of the ONTODAPS environment was consistent throughout. The results are presented in Table 33.

Table 33: Consistency of the presentation of the ONTODAPS environment

Strongly Disagree	Disagree	Uncertain	Agree	Strongly Agree	Std Dev	Std Error
0	0	1	11	6	0.2445	0.0576

Overall, 99% of the participants found the ONTODAPS presentation to be consistent while one participant was uncertain about its consistency. The participants generally had good impressions about ONTODAPS and how it could be useful to them in their learning.

6.3.6 Conclusions from Evaluation with Learners

From evaluating ONTODAPS with learners using various experiments, it could be seen that ONTODAPS enables learners to retrieve specific learning materials that are suitable for their learning needs, while considering their disability type. The level of precision in doing this is very good according to one participant with hearing impairment who stated that the feature she found most useful in ONTODAPS was that: *"it found the exact file types that I would have chosen to use myself"*.

Thus, by providing learners with learning materials that are suitable and appropriate to them and facilitating this task, it could be possible that learners could improve their learning when they assimilate this information.

6.4 Designing Inclusive Learning Environments

Having designed, implemented and evaluated the ONTODAPS model, the lessons learnt could be very useful to designers and developers of e-learning environments, who need to design inclusive learning environments. Thus, this section will focus on presenting lessons learnt from engaging in the evaluation and the recommendations on designing inclusive learning environments, from the point of view of students with disabilities.

6.4.1 Lessons Learnt from using ONTODAPS

Participants were asked the question: *What have you learnt from using the ONTODAPS environment?* Various interesting answers were given, some of which are discussed in this section. Some participants stated that by using ONTODAPS, they have found that learning with videos would be very helpful if the video has subtitles. This is very important particularly for learners with hearing impairment. By including captions or subtitles, they are able to watch the video and understand the information it conveys through the text in the video. Some participants with hearing impairments found videos in which the teacher was facing the camera while speaking very helpful because they could also read their lips; which improved understanding of the content.

Some of the participants found that by using ONTODAPS, they were able to use most of their senses, which to them was beneficial. For instance, they could be able to access learning materials in video format, making use of the sense of sight and could also make use of the sense of sound by listening to audio learning materials. To some users, that ability to have learning materials in different formats is very beneficial as they are able to access these materials and interact with them as they wish. One of the participants stated that he had become more aware of the needs of different learners.

6.4.2 Recommendations for Designing Inclusive Learning Environments

By carrying out the evaluation with students, observing their interaction and listening to their opinions on designing inclusive learning environments, specific recommendations for inclusive e-learning are presented in the following subsections. Participants were asked what considerations should be taken when designing learning environments for those with their disability type and what an ideal learning environment would be for them, considering design and functionality. By also asking what features of ONTODAPS were most useful to them, all the responses were used to provide these recommendations to those looking to design learning environments for learners with disability.

6.4.2.1 Appropriate format of Learning Materials per Disability Type

The participants were asked what format of learning materials was suitable for them, considering their disability type. The results are presented in Table 34.

Table 34: Preferred format of learning materials by disability type

Disability Type	Preferred Format of Learning Materials					
	Audio	Text	Video	Text+video	Audio and video with captions	Video with captions
Dyslexia	0	0	0	8	3	0
Hearing Impairment	0	1	0	1	0	1
Visual Impairment	0	2	0	0	0	0
Hearing Impairment+Dyslexia	0	1	0	0	0	1

Generally, those with dyslexia preferred a combination of text and video and in some cases, they preferred learning materials in audio and video formats provided that the video had captions. Those with dyslexia find audio and video helpful in that they are able to play, pause and rewind the audio/video materials. Those with hearing impairment had different preferences. For instance, one of them had a preference for

text only, which is quite understandable because due to disability, they might not be able to make the most of the sense of sound or video if it is not accompanied by captions. Another participant with hearing impairment preferred a combination of text and video because they could watch the video and reading the text would make it clearer, which is synonymous to having a video with captions, although one other participant with hearing impairment preferred a video with captions.

Of the two participants with hearing impairment and dyslexia, one preferred text only while the other preferred learning materials presented in a video format with captions. Thus it could be implied that due to dyslexia, the individual might have preference for video learning materials, but due to hearing impairment, the video needs to be captioned. This is in accordance with results from the Case Studies in Chapter 5, where ONTODAPS presents learning materials to different learners by analysing their disability types, the appropriate formats of learning materials for each disability type and then using various algorithms, presents the learner with learning materials in the appropriate format.

The two participants with visual impairment preferred materials in text format. This is not surprising because the loss of sight whether complete or partial means that the individual will not be able to make the most from learning materials that are visually presented. Hence, they can depend on the sense of sound. Thus, text-based materials could be read out loud using screen readers or better still, learning environments could incorporate such assistive technologies which could be invoked by the learner when needed.

A participant with dyslexia, when responding to the question on what format of learning materials is best suited to their disability type had this to say:

"Video, having the ability to see and remember the motions/drawings/teacher/notes all together helps my learning process. Having a document of text beside audio is also effective if the text file has the diagrams drawn on the board that the prof. draws".

6.4.2.2 Designing for Learners with Visual Impairment

In an initial evaluation of ONTODAPS at the University of Hull, some of the visually impaired participants while interacting with ONTODAPS had an affinity to control the font type, face and size of the interface. This suggests that this control over a learning environment is very important for them particularly those with low vision, who may need some form of magnification in order to read text. This was not only observed amongst visually impaired participants but was also observed amongst some with dyslexia or those with some reading problems. In both groups of people, the ability to change the background colour was also very important as the contrast between the font and the background of the interface is very important.

Visually impaired users also find speech interface very helpful. One of the participants with low vision found this feature of ONTODAPS very helpful as it gave them clues on what they were doing. However, when such speech is included in a learning environment, learners with disability also want to have control over such speech, particularly those with dyslexia. A participant with dyslexia suggested that the learner should be able to control the speed, volume and possibly choose which type of English (British, American, etc.) to read the text with.

6.4.2.3 Designing for Learners with Hearing Impairment

Whilst learners with a specific learning difficulty such as dyslexia or reading difficulties may find audio and video very helpful, those with hearing impairment generally prefer text formats. However, videos need to be accompanied with captions for them to be able to fully access the information as earlier discussed.

In their suggestions on how to design learning environments and materials that meet their needs, the participants with hearing impairment stated that instructions should be available in text format. However, some stated that pairing captioned video with text would be very beneficial. One of the participants with hearing impairment had this to say:

"Even if there is no video available, it is nice to pair audio and video formats- it helps to keep track of reading and set a pace".

All the above recommendations become more complicated when the learner has multiple disabilities.

6.4.2.4 Designing for Learners with Multiple Disabilities

Two of the participants in this study had more than one disability and were thus classed as having multiple disabilities. For such individuals, a learning environment needs to consider their disabilities and provide learning resources in appropriate formats as described in the Case Studies section in Chapter 5.

One of such cases of multiple disabilities involved a participant with both hearing impairment and dyslexia. This individual could not read any text information without highlighting the text to give a better contrast. Responding to how learning environments could be designed to include their needs, the participant had this to say:

"The way that learning environments could adapt to my learning disabilities and hearing difficulties would be if I can change the text and the background colour so that the text is much clearer for me to read"

She thus ruled out the need for any audio or video, preferring text with the ability to control how the text is presented. This is very important if she would understand the information presented.

6.4.2.5 Designing for Learners with Dyslexia

As already explained above, most of the participants with specific learning difficulty such as dyslexia preferred learning materials that were presented in a format making use of a combination of text and video while others preferred learning materials in a format using captioned video. However, when allowed to choose which format to access the tutorial, some chose text while others chose video with none preferring to listen to the audio tutorial. Video formats could be very helpful for those with moderate to severe learning difficulties while those with mild learning difficulties readily chose text formats.

It is important to include multiple formats of learning resources for learners to choose their preferred format. Some participants during this study found that such multiple formats allow them to consult a different media format if they failed to understand a topic as it will help them double check information. Additionally, some students indicated that these multiple formats are still very good for those without disabilities because they may have different learning styles.

Some students with dyslexia suggested that learning environments should contain a good help menu so that they could always refer to it when they have any difficulties with the environment. This help menu will be very useful if it also contains such help information in multiple formats to meet the needs of various learners as recommended during heuristic evaluation.

When asked how learning environments could be designed to meet their needs, one of the participants with dyslexia stated that learning environments need to include diagrams and images as well as video. This participant also stated the need to "*increase visual appearance because this helps relax users and helps the learning experience*".

6.4.3 Conclusions

In Chapter 1, the hypothesis underlying this research was stated as follows:

Learning materials can be personalised for learners with disabilities, including those with multiple disabilities by developing a model that allows the learning environment to present learners with materials in suitable formats while considering their learning needs.

The ONTODAPS model that was developed in Chapters 4 and 5 was evaluated in Chapters 5 and 6 using case studies and experiments respectively. The results presented for the experimental evaluation of ONTODAPS suggest that ONTODAPS is flexible enough to enable users to retrieve learning materials in formats that are appropriate for their needs, considering their disability type (s) and learning goals.

Thus ONTODAPS by providing equal access to learning resources through an ontology-driven disability-aware personalisation provides equivalent access to learning resources and equivalent learning experiences which could potentially help to improve learning.

To sum it all up, in this age of social media and Web 2.0, learners want the ability to control the learning environment by being able to personalise it. One way to do this could be for them to drag and drop things around, add or remove features they do not need.

Users interacting with the ONTODAPS system mainly liked the personalisation it offers in terms of aggregating learning resources and presenting them in formats that are suitable for their specific needs. They thus recommended that online learning environments should provide this possibility of personalising modules and their learning resources in addition to presenting such resources in multiple formats.

6.5 Summary

This chapter has presented the results of the experimental evaluation of ONTODAPS by some experts (heuristic evaluation) and some students. In the heuristic evaluation, participants evaluated the visual interface of ONTODAPS following some established heuristics. The evaluation by students was done by using baseline (without ONTODAPS) and intervention (with ONTODAPS) tests. The performance of ONTODAPS was measured considering precision, recall and F-value. The results of the evaluations were presented and discussed. The chapter ended by providing some recommendations on designing more inclusive learning environments, considering the opinions of students with disabilities and based on observations of the participants' interaction with ONTODAPS during the evaluation.

The following chapter will provide a conclusion to this research, revisiting the research objectives and also presenting the contributions of this research as well as suggestions on how this work could be extended.

Chapter 7: Conclusions and Future Research

7.1 Overview

The previous chapter presented the evaluation of the ONTODAPS model by 10 lecturers and 18 students with disabilities. This chapter presents a summary of the research conclusions and also presents possible future research arising from this work. The research objectives outlined in Chapter 1 are revisited including the main findings then the contributions are presented and discussed. A critique of the work is also presented.

7.2 Research Findings

Existing learning environments are not designed to accommodate the needs of students with disabilities, particularly those with multiple disabilities as these inflexibly designed systems cannot adapt to the needs of these students. It has been acknowledged in literature that it is difficult to design for cases of multiple disabilities and this is also evident in the fact that most of the learning environments built for students with disabilities have focused on helping those with a specific disability.

By considering how learners with disabilities could interact with learning materials in a learning environment, this thesis argued that it is possible to personalise learning materials for learners with disabilities, including those with multiple disabilities by developing a model that allows the learning environment to present the student with learning materials in suitable formats while considering their learning needs.

In order to assess and support this hypothesis, some objectives were set in Chapter 1 of this thesis. In this section, those research objectives will be revisited in order to summarise how they have been achieved.

Objective 1. *Provide a critical review of literature in the field of learning, disability and personalised e-learning particularly relating to students with disabilities.*

In Chapter 2, this thesis critically examined published work on learning theories, personalised learning and e-learning, including the topic of disability. Based on Chapters 1-3, the following main findings were obtained:

The sheer amount of information online poses a problem with information retrieval. Thus it is difficult to retrieve the correct learning materials from numerous materials in learning environments (Salehi and Kamalabadi, 2013). This is even more challenging for students with disabilities as Debevc et al. (2010) suggested that such individuals would need an adapted environment for education.

According to Power et al. (2010), e-learning can be positively used to present learning materials to students with disabilities in adapted forms that meet their special needs. Nevertheless, existing learning environments do not offer adequate adaptations to meet the needs of learners (Peter et al., 2010, Tompsett, 2008, Devedzic, 2004), particularly those with disabilities. Even when learning environments are designed to meet the needs of students with disabilities, most of them have only targeted the needs of individuals with a specific disability (Sampson and Zervas, 2011). For instance, learning environments have been designed to cater for the needs of students with dyslexia only while others have been designed specifically for people with visual impairment. Current e-learning environments do not therefore meet the needs of people with multiple disabilities. Petrie et al. (2006) note that it is difficult to design for cases of multiple disabilities. If the above trend is followed, it might imply that separate learning environments will be designed for learners with specific disabilities. Therefore, if a learner has two or more disabilities, they will have to use two or more learning environments in order to achieve their learning goals for a specific course.

Nevertheless, Guenaga et al. (2004) as well as Fichten et al. (2009a) advocate a “design for all” or “universal design” approach when designing e-learning systems in order to meet the needs of all individuals. Newell et al. (2010) however, do not think a universal design approach is feasible and recommend an approach which is user-sensitive and inclusive and thus more achievable.

The ONTODAPS learning environment builds on these findings by introducing the ability to adapt not only to a single disability, but to several disabilities. By using semantic web technologies to model the learner and the learning content and granting the learner the ability to interact with the ontology from their profile, information in the ontology can readily be manipulated. With disability, it is possible that an individual's case can become better, worse or an individual can develop other disabilities. So, ONTODAPS accommodates this by allowing the learner to add different types of disabilities into the ontology through the profile and then the system recommends appropriate formats of learning materials.

Objective 2. *Design a model for personalising learning materials for students with disabilities based on filtration technique.*

The need for a new model arose from findings from literature in Chapter 2 as discussed above, which showed that existing learning environments do not sufficiently meet the needs of learners, specifically those with disabilities. Also, as discussed in Chapter 1, there is the problem of being able to retrieve the correct learning material from a vast array of learning materials (Salehi and Kamalabadi, 2013) which for students with disabilities becomes even more difficult when the wrong format of presenting the learning material is chosen (Power et al., 2010). In Chapter 3, various approaches to design learning systems for people with disabilities were examined and it was determined that user-centred approaches like the inclusive design approach would lead

to a system that better meets the needs of the user. In literature, the case for a user sensitive inclusive design approach was made by Newell et al. (2010). In Chapter 3, a disability-aware approach which is specific for people with disabilities was discussed. The subject of web ontologies was discussed in Chapter 3 but earlier in Chapter 2, ontology-based personalisation of learning was discussed. It was seen from these chapters that ontologies make more meaning and are the best solution for developing meaningful learning environments that ensures adaptation and personalisation and that web ontologies could be used to model the learner and the courses to facilitate search, retrieval and presenting the correct format of learning materials to the learner. The ONTODAPS model which adopts an ontology-driven and disability-aware approach, presented in Chapter 4, was thus designed to present students who have disabilities with the correct format of learning materials based on their learning goals and disability types. Thus, through various algorithms, learners are matched with the learning materials that meet their needs. Additionally, searching and retrieving learning materials is very easy. By using the concept of a community of agents (Nganji and Brayshaw, 2011), the different components of the ONTODAPS model work together to effectively respond to the needs of the learner.

Objective 3. *Demonstrate through case studies how the e-learning model provides personalisation for single and multiple cases of disabilities and for a student without disabilities.*

As discussed above, Guenaga et al. (2004) as well as Fichten et al. (2009a) advocate a universal design approach in order to include the needs of all learners with disabilities. This also means such a system should not only meet the needs of those with disabilities, but should also be able to meet the needs of those without disabilities. As demonstrated in Chapter 5 through various case studies, the ONTODAPS model can meet the needs

of all learners, regardless of disability. Modelling the learner and their needs through semantic technologies can allow for easy manipulation and retrieval of specific information through algorithms. The ONTODAPS model allows learners without disabilities to indicate through their profile that they do not have any disability and this information is stored in the ADOOLES ontology. When they request learning materials related to a specific learning goal, they are then presented with learning materials in audio, video and text formats and they can then choose the format of their choice. The case studies in Chapter 5 show that it is possible to personalise learning for students with disabilities, including those with multiple disabilities as stated in the hypothesis. Thus, flexible systems can be built using an approach that considers the needs of the user and employing semantic web technologies.

Objective 4. *Implement a prototype of the proposed model.*

As explained in Chapter 5, the users and learning materials as well as courses were modelled with web ontologies. This work was influenced by works such as Schmidt & Schneider (2007) and Tzouveli et al. (2008b) in order to present an adaptive learning environment for the needs of learners with disabilities. However, considering the challenges of personalising for multiple cases of disabilities, this research contributed to bridging the gap in literature by ensuring that individual disabilities within the learner are analysed separately and then collectively to see how they affect the individual in order to determine the best format for presenting the information. The learner is then given the ability through their profile to choose more than one disability type for the learning environment to adapt to their needs.

Objective 5. *Evaluate the approach using various experiments with lecturers (heuristic evaluation) and students (experimental evaluation).*

In Chapter 6, the approach in this thesis was tested using experts in the heuristic evaluation and students with disabilities in the experimental evaluation. The experts were lecturers at the University of Hull who are skilled with evaluation. In the heuristic evaluation, the experts did not expect to see any major difficulties with students using ONTODAPS to personalise learning materials. In the experimental evaluation with students, most of the students found ONTODAPS to offer appropriate personalisation to meet their learning needs. They found that by using ONTODAPS, it could aid their learning experience and all agreed that they would like to use this functionality in an existing learning environment.

Having revisited the objectives of this study, its contributions will be examined next.

7.3 Research Contributions

After a literature review, analysis, design, implementation and evaluation of a system for recommending and retrieving learning materials for students with disabilities, this thesis has made the following contributions to e-learning personalisation for students with disabilities:

7.3.1 Development of an ontology-driven and disability-aware e-learning model

Existing architectures were studied and whilst those that are ontology-based result in improved personalisation to meet the needs of users, most of these architectures were designed for users without disabilities. The few existing ontology-based approaches for solving difficulties faced by students with disabilities do not have a mechanism that adjusts to the needs of learners with multiple disabilities, hence cannot provide any meaningful personalisation of e-learning resources for them. Consequently, a model was

developed that contains different agents, each performing specific functions and by intercommunicating, bring about an effective solution to the needs of the users (with or without disabilities).

By identifying users with multiple disabilities, the knowledge representation component which contains the ADOOLES ontology communicates with the information presentation component to present such users with the e-learning resources that meet their disability and learning needs in the appropriate format. The complete architectural model with descriptions of the functions of the individual agents was presented in Chapter 4.

7.3.2 Development of a disability ontology

Numerous ontologies have been designed and are available online for reuse; however, very few of such have been designed to meet the needs of people with disabilities. From searching the web for ontologies to reuse, the author came across no ontology that could be used in its entirety for this study. A disability ontology known as ADOLENA - developed by Keet et al (2008) - was obtained after contact with the main author. Upon studying the ontology, it only appeared necessary to reuse part of it in the process of developing the ontology used in this study, known as ADOOLES, which is used for personalising e-learning and related services for students with disabilities. The ADOLENA ontology needed to be extended because it did not have some of the concepts related to learning that were needed for the ONTODAPS system. The ADOOLES ontology incorporates concepts used by the Higher Education Statistics Agency (HESA) to describe disabilities in education, some of which are not found in the ADOLENA ontology. This ontology can be reused for other projects related to students with disabilities and could be used to personalise learning environments as it

also contains assistive mechanisms. The ADOOLES ontology with its classes and properties were described in Chapter 4.

7.3.3 E-learning visual interface design

In evaluating the ONTODAPS model, such evaluation could be facilitated if users and experts could carry out the evaluation. In order to test the efficacy of the ontology-driven and disability-aware model in personalising learning resources for students with disabilities, the visual interface of ONTODAPS was implemented to enable users to manipulate the model through the graphical user interface. The visual interface identifies the needs of the user after logging in to the system and presents them with personalised learning resources whilst considering their learning goals, disability type and preferences. Chapter 5 presents its implementation.

7.3.4 E-learning model evaluation

The ONTODAPS model was evaluated using two methods. Experimental evaluation by student users who interacted with the visual interface and carried out specific tasks before filling in evaluation questionnaires. By carrying out user evaluation, it was shown that ONTODAPS can provide efficient personalisation for both students with and without disabilities, including those with multiple disabilities and that ONTODAPS can provide a means of effectively managing vast numbers of learning resources that may be found in an e-learning environment. This is very important because some students with disabilities might struggle in browsing through large numbers of resources (Salehi and Kamalabadi, 2013). The heuristic evaluation also provided results that could be used to judge the effectiveness of ONTODAPS in addition to its usability.

7.3.5 Increased access to learning materials

By recommending learning materials in formats that are appropriate for the disability of individuals, this research contributes to increasing access to learning and hence contribution to disability inclusion, in compliance with contemporary disability legislations.

7.3.6 Recommendations for inclusive e-learning system design

The post interaction usability questionnaire given to students with disabilities contained additional room for them to suggest how online learning environments could be designed to meet their needs. This qualitative data was collected and presented, which represents suggestions for designing more inclusive learning environments. This presents students with disabilities' voices on designing inclusive learning environments. The fact that the research included users with disability as evaluators who had varying types of disabilities, including some with multiple disabilities, gives a strong voice as students with disabilities know what difficulties they face when using learning environments and hence could best make recommendations for inclusive design.

Disability is an individual experience and hence the individual recommendations of various students with disabilities are very important.

7.3.7 Contribution to literature

This thesis makes a contribution to literature in the field of personalised e-learning for students with disabilities through a review of literature in the field as presented in Chapter 2 and through the publications that have arisen as a result of this research as listed in the preliminary pages of this thesis.

7.4 Future Research

This research provides some important direction for future research on meeting the needs of students with disabilities when accessing e-learning systems. Most e-learning systems have been found to be inaccessible and do not provide efficient personalised learning thus excluding some students with disabilities. In order to continue this work, the following future research work has been identified.

i. Testing ONTODAPS with larger and more diverse groups of students

The results of evaluating ONTODAPS presented in Chapter 6 give meaningful insight into how a learning environment could meet the needs of students with disabilities, including those with multiple disabilities. However, for these findings to be generalised and in order to obtain more useful insights, it would be good to carryout larger scale experiments amongst students with disabilities and include different types of disabilities. To do this, enough time will need to be allocated in order to recruit an adequate number of participants.

ii. Deploying ONTODAPS as personalisation mechanism into an e-learning system

More research could be carried out on incorporating the ONTODAPS personalisation mechanism into existing e-learning environments and testing to see its effectiveness in a large scale. This need arises from the fact that most students with disabilities who participated in the evaluation found the personalisation offered very helpful and will like to see this type of personalisation offered in existing e-learning systems.

If this is done, it will enhance existing e-learning systems and make them better learning environments inclusive of all learners.

iii. Incorporating diversified interaction methods

Currently, ONTODAPS relies on keyboard and mouse input for users to interact with the system. Future research could look at extending the implementation of the visual interface to accommodate interaction through speech via speech recognition software and other input methods including tactile.

The needs of users with more difficult combinations of disabilities such as blindness and deafness should be investigated and a mechanism for providing personalised e-learning for such cases should be developed, for such system to be more inclusive than it is now. With the increasing number of students with disabilities in education, it is possible that users with such special cases will gain admission into educational institutions and will need “reasonable adjustments” to learning environments.

iv. Deploying ONTODAPS as a web-based e-learning system

With the presence of Web 2.0 technologies and social media where students engage with media, ONTODAPS could be deployed on the web to enable better access to numerous people anywhere and at any time. In doing this, issues related to web-based systems such as privacy and security will need to be considered. This deployment will then need to be tested with a vast number of students to see how effective web-based ONTODAPS is.

v. Evaluation of the ADOOLES ontology

Poveda-Villalon et al. (2014) note that although using the correct ontology development methodology could assure the quality of the ontology, there may be some difficulties during the development which may result in some anomalies in the ontology that has been developed. According to Gomez-Perez (2001), ontologies should be evaluated for consistency, completeness, conciseness, expandability and sensitiveness. Although

ADOOLES was checked for consistency with the FaCT++ reasoner, there remains a need to check its full technical quality through a more comprehensive evaluation of the ontology.

7.5 Reflections on the research process

Whilst studying literature, it was discovered that most systems are still inaccessible to people with disabilities due to the methodology used to develop them. It was thus necessary to develop a new method of designing accessible and usable systems. This research involved consulting some students with disabilities and experts in disability during the early stages of literature review as well as speaking to a visually impaired member of staff and obtaining their opinion on user testing. The methodology involved improving existing software development methodologies to incorporate disability-aware processes which helped to improve the accessibility and usability of the system that was designed. This methodology was a good choice as it was disability-aware and thus inclusive.

The ONTODAPS visual interface was implemented in Java. Whilst Java could be used to provide effective personalisation, it was lacking in its ability to be used to provide more flexibility. Future implementation will be better implemented using web programming languages such as Java Server Pages (JSP) or other languages. A web-based implementation as already discussed will enable users to access the system at their convenience.

The use of OWL to drive ONTODAPS means that both humans and machines can understand the information presented and thus can be used to provide a more effective personalisation as shown in the evaluation results. Thus, semantic web technologies will

provide a better knowledge base that will enable interoperability and portability to other systems.

As already discussed in Chapter 5 and above, the ONTODAPS visual interface was only evaluated by 18 students with disabilities. Amongst the students with disabilities, there were more students with dyslexia than other disabilities. The time taken for the evaluation might not have been sufficient enough for more students with disabilities to come forward and participate. Future evaluation will need to be done over a longer period of time and include equal numbers from each category. Nevertheless, the results provide a meaningful insight into how learning environments can be designed to meet the needs of students with disabilities and help inform decisions on improving ONTODAPS.

To conclude, all sets of users gave positive feedback about ONTODAPS and it can be seen from the results that ONTODAPS is a good e-learning system with no catastrophic usability problems which can be effectively employed to personalise learning and to manage learning resources. This implies that ONTODAPS is a medium where students with disabilities can have equivalent learning experience with their peers without disability. This could potentially increase access to learning for students with disabilities and possibly help improve their results due to increase in accessibility of learning resources and usability of the system. This system thus complies with contemporary legislation which requires “reasonable adjustments” or “reasonable accommodations” to be made to meet the needs of people with disabilities.

7.6 Thesis Conclusions

This thesis considers the challenges faced by students with disabilities when accessing existing learning environments, specifically the difficulties of adapting to the needs of

learners with multiple disabilities. The literature review in Chapter 2 revealed that existing learning environments are not flexible enough to accommodate the needs of learners with disabilities, particularly those with multiple disabilities. A new ontology-driven and disability-aware model called ONTODAPS was developed to facilitate retrieval of learning materials from a learning environment. The ONTODAPS model responds to the needs arising from the literature review by allowing for the needs of learners with multiple disabilities to be incorporated into learning environments and to recommend learning materials that meet the needs of all learners.

Results from the evaluation of ONTODAPS with experts and students with disabilities suggest that the ontology-driven and disability-aware approach can provide appropriate personalisation of learning materials for students with disabilities and helps in retrieving materials from a huge repository of learning materials. The results show that although it is difficult to design for cases of multiple disabilities, it is possible and hence learning environments can be designed to incorporate the needs of learners with disabilities, including those with multiple disabilities. To generalise these results however, further testing needs to be carried out amongst students in a larger scale and across different institutions.

REFERENCES

- AIMEUR, E., GAMBS, S. & HO, A. 2010. Towards a Privacy-enhanced Social Networking Site. *Fifth International Conference on Availability, Reliability, and Security: Ares 2010, Proceedings*, 172-179.
- AL-KHALIFA, H. S. & DAVIS, H. C. 2006. The Evolution of Metadata from Standards to Semantics in E-Learning Applications. *Hypertext'06*. Odense., Denmark.
- AL-KHALIFA, H. S. & DAVIS, H. C. 2007. Replacing the monolithic LOM: A folksonomic approach. *7th IEEE International Conference on Advanced Learning Technologies, Proceedings*, 665-669.
- ALBION, P. 1999. Heuristic evaluation of educational multimedia: from theory to practice. *ASCILITE 1999: 16th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education: Responding to Diversity*. Brisbane, Australia.
- ALLAN, B. 2007. *Blended Learning Tools for Teaching and Training*, London, Facet Publishing.
- ALLY, M. 2004. Foundations of educational theory for online learning. In: ANDERSON, T. & ELLOUMI, F. (eds.) *Theory and practice of online learning*. Athabasca: Athabasca University.
- ALONSO, F., LOPEZ, G., MANRIQUE, D. & VINES, J. M. 2005. An instructional model for web-based e-learning education with a blended learning process approach. *British Journal of Educational Technology*, 36, 217-235.
- ALTAY, B. 2014. User-centered design through learner-centered instruction. *Teaching in Higher Education*, 19, 138-155.
- AROYO, L., POKRAEV, S. & BRUSSEE, R. 2003. Preparing SCORM for the Semantic Web. *On the Move to Meaningful Internet Systems 2003: Coopis, Doa, and Odbase*, 2888, 621-634.
- ASUNCION, J. V., FICHTEN, C. S., FERRARO, V., CHWOJKA, C., BARILE, M., MAI NHU, N. & WOLFORTH, J. 2010. Multiple Perspectives on the Accessibility of E-Learning in Canadian Colleges and Universities. *Assistive Technology*, 22, 187-199.
- BACHTOLD, M. 2013. What Do Students "Construct" According to Constructivism in Science Education? *Research in Science Education*, 43, 2477-2496.
- BALATSOUKAS, P., GAROUFALLOU, E., ASDERI, S. & SIATRI, R. 2011. A Survey on the Importance of Learning Object Metadata for Relevance Judgment. *Metadata and Semantic Research*, 240, 300-311.
- BELL, B. S. & FEDERMAN, J. E. 2013. E-Learning in Postsecondary Education. *Future of Children*, 23, 165-185.
- BENBASAT, I., GOLDSTEIN, D. K. & MEAD, M. 1987. The Case Study Research Strategy in Studies of Information Systems. *MIS Quarterly*, September, 369-387.
- BENGISU, M. 2010. Assistive Technologies for Visually Impaired Individuals in Turkey. *Assistive Technology*, 22, 163-171.
- BERGMAN, M. 2007. *An Intrepid Guide to Ontologies* [Online]. Available: <http://www.mkbergman.com/374/an-intrepid-guide-to-ontologies/> [Accessed 4 November 2011].
- BERNARAS, A., LARESGOITI, I., BARTOLOME, N. & CORERA, J. 1998. Building and using an electrical network ontology for fault diagnosis. *Engineering Intelligent Systems for Electrical Engineering and Communications*, 6, 3-11.

References

- BERNERS-LEE, T., HENDLER, J. & LASSILA, O. 2001. The Semantic Web - A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities. *Scientific American*, 284, 34-+.
- BHARUTHRAM, S. & KIES, C. 2013. Introducing e-learning in a South African Higher Education Institution: Challenges arising from an intervention and possible responses. *British Journal of Educational Technology*, 44, 410-420.
- BILETSKIY, Y., BAGHI, H., KELEBERDA, I. & FLEMING, M. 2009. An adjustable personalization of search and delivery of learning objects to learners. *Expert Systems with Applications*, 36, 9113-9120.
- BILLSUS, D. & PAZZANI, M. A Personal News Agent that Talks, Learns and Explains. 3rd International Conference on Autonomous Agents (Agents 99), 1999 Seattle, Washington.
- BLINKHORN, P., EVANS, G., KING, A., KURNIAWAN, S. H. & SUTCLIFFE, A. 2003. Screen Magnifiers: Evolution and Evaluation. *IEEE Computer Graphics and Applications*, 23, 54-61.
- BLOMBERG, J. L. & HENDERSON, A. 1990. Reflections on participatory design: lessons from the trillium experience. *SIGCHI Conference on Human Factors in Computing Systems (CHI '90)*. Seattle, USA.
- BOETHEL, M. & DIMOCK, K. V. 1999. Constructing knowledge with technology. Austin.
- BOHL, O., SCHELLHASE, J., SENGLER, R. & WINAND, U. 2002. The sharable content object reference model (SCORM) - A critical review. *International Conference on Computers in Education, Vols I and II, Proceedings*, 950-951.
- BRADFORD, P., PORCIELLO, M., BALKON, N. & BACKUS, D. 2006. The Blackboard Learning System: The Be All and End All in Educational Instruction? *Journal of Educational Technology Systems*, 35, 301-314.
- BRAIDA, F., MELLO, C. E., PASINATO, M. B. & ZIMBRAO, G. 2015. Transforming collaborative filtering into supervised learning. *Expert Systems with Applications*, 42, 4733-4742.
- BRASE, J. & NEJDL, W. 2004. Ontologies and Metadata for eLearning. In: STAAB, S. & STUDER, R. (eds.) *Handbook on Ontologies*. Springer.
- BRAYSHAW, M., GORDON, N., NGANJI, J., WEN, L. P. & BUTTERFIELD, A. 2014. Investigating Heuristic Evaluation as a Methodology for Evaluating Pedagogical Software: An Analysis Employing Three Case Studies. *Learning and Collaboration Technologies: Designing and Developing Novel Learning Experiences, Pt I*, 8523, 25-35.
- BURKE, R. 2002. Hybrid recommender systems: Survey and experiments. *User Modeling and User-Adapted Interaction*, 12, 331-370.
- BURKE, R. 2005. Hybrid systems for personalized recommendations. *Intelligent Techniques for Web Personalization*, 3169, 133-152.
- BUTTERWORTH, B., VARMA, S. & LAURILLARD, D. 2011. Dyscalculia: From Brain to Education. *Science*, 332, 1049-1053.
- CABRERA-UMPIERREZ, M. F., VILLALAR, J. L., ARREDONDO, M. T., GAETA, E. & LAZARO, J. P. 2007. Enhancing the safety feeling of mobility impaired travellers through infomobility services. *Universal Access in Human-Computer Interaction: Ambient Interaction, Pt 2, Proceedings*, 4555, 285-292.
- CAKMAK, E. & YILMAZ, S. M. 2014. E-learning from the perspective of right to education. *5th World Conference on Educational Sciences*, 116, 426-430.
- CALVO, R., IGLESIAS, A. & MORENO, L. 2012. Is Moodle Accessible for Visually Impaired People? *Web Information Systems and Technologies*, 101, 207-220.
- CAMINERO, A. C., HERNANDEZ, R., ROS, S., ROBLES-GOMEZ, A., TOBARRA, L. & IEEE. 2013. Choosing the right LMS: A performance evaluation of three

References

- open-source LMS. IEEE Global Engineering Education Conference (EDUCON), Mar 13-15 2013 Berlin, GERMANY. NEW YORK: Ieee, 287-294.
- CANTADOR, I., BALLOGIN, A. & CASTELLS, P. Ontology-based Personalised and Context-aware Recommendations of News items. Proceedings of the 2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology, 2008. 562-565.
- CANVAS. 2014. *Canvas Learning Management System* [Online]. Available: <https://www.canvas.net/> [Accessed September 1 2014].
- CARVALHO, A., AREAL, N. & SILVA, J. 2011. Students' perceptions of Blackboard and Moodle in a Portuguese university. *British Journal of Educational Technology*, 42, 824-841.
- CHAKRABORTI, P., TOPRAKCI, H. A. K., YANG, P., DI SPIGNA, N., FRANZON, P. & GHOSH, T. 2012. A compact dielectric elastomer tubular actuator for refreshable Braille displays. *Sensors and Actuators a-Physical*, 179, 151-157.
- CHEN, Q., GRUNDY, J. & HOSKING, J. 2008. SUMLOW: early design-stage sketching of UML diagrams on an E-whiteboard. *Software Practice & Experience*, 38, 961-994.
- CHILDRESS, S. & BENSON, S. 2014. Personalized learning for every student every day. *Phi Delta Kappan*, 95, 33-38.
- CHOI, O. & HAN, S. 2008. Personalization of rule-based web services. *Sensors*, 8, 2424-2435.
- CHOI, S. H., JEONG, Y. S. & JEONG, M. K. 2010. A Hybrid Recommendation Method with Reduced Data for Large-Scale Application. *Ieee Transactions on Systems Man and Cybernetics Part C-Applications and Reviews*, 40, 557-566.
- CHOOKAEW, S., PANJABUREE, P., WANICHAN, D. & LAOSINCHAI, P. 2014. A Personalized E-Learning Environment to Promote Students' Conceptual Learning on Basic Computer Programming. *5th World Conference on Educational Sciences*, 116, 815-819.
- CLARKE, T. 2013. The advance of the MOOCs (massive open online courses). *Education + Training*, 55, 403-413.
- CLEMENTS, D. H. & SARAMA, J. 2011. Early Childhood Mathematics Intervention. *Science*, 333, 968-970.
- COFFIELD, F., MOSELEY, D., HALL, E. & ECCLESTONE, K. 2004. *Learning Styles and Pedagogy in post-16 learning: a systematic and critical review* [Online]. Available: <http://www.lsda.org.uk/files/PDF/1543.pdf> [Accessed September 6 2010].
- COLL, C. & ENGEL, A. 2014. Making meaning through joint activity in Computer-Supported Collaborative Learning (CSCL) settings: The interplay between content-related and activity-related talk. *Anales De Psicologia*, 30, 818-831.
- CONDRUZ-BACESCU, M. 2013. CULTURAL CHALLENGES OF E-LEARNING. *Quality and Efficiency in E-Learning, Vol 1*, 573-578.
- CONLAN, O., DAGGER, D. & WADE, V. Towards a Standards-based Approach to e-Learning Personalization using Reusable Learning Objects. In: RICHARDS, G., ed. Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, 2002. 210-217.
- COOPER, M. & HEATH, A. 2009. Access For all to eLearning. In: MÉNDEZ-VILAS, A., SOLANO MARTÍN, A., MESA GONZÁLEZ, J. A. & MESA GONZÁLEZ, J. (eds.) *Research Reflections and Innovations in Integrating ICT in Education*. Badajoz, Spain: FORMATEX,.
- CORNOLDI, C. & VECCHI, T. 2000. *Mental imagery in blind people: The role of passive and active visuo-spatial processes*, Oxford, Oxford University Press.

References

- CORRALL, S. & KEATES, J. 2011. The subject librarian and the virtual learning environment A study of UK universities. *Program-Electronic Library and Information Systems*, 45, 29-49.
- COSTELLO, R. 2012. *Adaptive Intelligent Personalised Learning (AIPL) Environment*. PhD, The University of Hull.
- COX, M. J. 2013. Formal to informal learning with IT: research challenges and issues for e-learning. *Journal of Computer Assisted Learning*, 29, 85-105.
- COYLE, D., DOHERTY, G. & IEEE COMPUTER, S. O. C. 2008. Towards Ontologies for Technology in Mental Health Interventions. *Ontoract 2008: First International Workshop on Ontologies in Interactive Systems, Proceedings*, 18-26.
- D2L. 2014. *D2L Learning Environment* [Online]. Available: <http://www.brightspace.com/products/learning-environment/> [Accessed September 6 2014].
- DAGGER, D., CONLAN, O. & WADE, V. P. 2003. An Architecture for Candidacy in Adaptive eLearning Systems to Facilitate the Reuse of Learning Resources. *World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education (E-Learn 2003)*. Phoenix.
- DALRYMPLE, P. W. 1991. USER-CENTERED EVALUATION OF INFORMATION-RETRIEVAL. *Evaluation of Public Services and Public Services Personnel*, 32, 85-102.
- DATTA, P. & PALMER, C. 2015. Insights Into the Support Services for Students With Vision Impairment. *Australasian Journal of Special Education*, 39, 143-158.
- DAVIDS, M. R., CHIKTE, U., GRIMMER-SOMERS, K. & HALPERIN, M. L. 2014. Usability testing of a multimedia e-learning resource for electrolyte and acid-base disorders. *British Journal of Educational Technology*, 45, 367-381.
- DE BRA, P., HOUBEN, G.-J. & WU, H. 1999. AHAM: A Dexter-based Reference Model for Adaptive Hypermedia. *ACM Conference on Hypertext and Hypermedia*.
- DE CAMPOS, L. M., FERNANDEZ-LUNA, J. M., HUETE, J. F. & RUEDA-MORALES, M. A. 2010. Combining content-based and collaborative recommendations: A hybrid approach based on Bayesian networks. *International Journal of Approximate Reasoning*, 51, 785-799.
- DEBEVC, M., KOSEC, P. & HOLZINGER, A. 2010. E-Learning Accessibility for the Deaf and Hard of Hearing - Practical Examples and Experiences. *Hci in Work and Learning, Life and Leisure*, 6389, 203-213.
- DECKER, S., MELNIK, S., VAN HARMELEN, F., FENSEL, D., KLEIN, M., BROEKSTRA, J., ERDMANN, M. & HORROCKS, I. 2000. The semantic Web: The roles of XML and RDF. *Ieee Internet Computing*, 4, 63-74.
- DEVEDZIC, V. 2004. Education and the Semantic Web. *International Journal of Artificial Intelligence in Education*, 14, 39-65.
- DFES 2001. *Guidance to support pupils with dyslexia and dyscalculia*, DfES Publications.
- DICHEVA, D. 2008. Ontologies and Semantic Web for e-Learning. In: PAWLOWSKI, J. M., ADELSBERGER, H. H., KINSHUK & SAMPSON, D. (eds.) *Handbook on Information Technologies for Education and Training*. 2nd ed. Berlin Heidelberg: Springer-Verlag.
- DIUS. 2009. *Disabled Students and Higher Education* [Online]. Department for Innovation Universities and Skills. Available: http://www.bis.gov.uk/assets/biscore/corporate/migratedd/publications/d/dius_rr_09_06.pdf [Accessed 31 March 2011].

References

- DOLOG, P., HENZE, N., NEJDL, W. & SINTEK, M. Personalization in distributed e-learning environments. Proceedings of the 13th International World Wide Web conference on Alternate track papers & posters, 2004a New York, USA. 170-179.
- DOLOG, P., HENZE, N., NEJDL, W. & SINTEK, M. 2004b. The personal reader: Personalizing and enriching learning resources using semantic web technologies. *Adaptive Hypermedia and Adaptive Web-Based Systems, Proceedings*, 3137, 85-94.
- DOUCE, C., PORCH, W. & COOPER, M. 2010. Adapting E-Learning and Learning Services for People with Disabilities. *1st International AEGIS Conference: Access for All in the Desktop, Web and Mobile Field: an End-User and Developer Perspective*. Seville, Spain.
- DRAFFAN, E. A., EVANS, D. G. & BLENKHORN, P. 2007. Use of assistive technology by students with dyslexia in post-secondary education. *Disabil Rehabil Assist Technol*, 105-116.
- DRIGAS, A., KOUKIANAKIS, L., PAPAGERASIMOU, Y. & IEEE 2006. An e-learning environment for nontraditional students with sight disabilities. *36th Annual Frontiers in Education, Conference Program, Vols 1-4: BORDERS: INTERNATIONAL, SOCIAL AND CULTURAL*.
- DUNN, S. 2003a. Return to SENDA? Implementing accessibility for disabled students in virtual learning environments in UK further and higher education.
- DUNN, S. 2003b. *Return to SENDA? Implementing accessibility for disabled students in virtual learning environments in UK further and higher education* [Online]. Available: <http://www.saradunn.net/VLEreport/section04.html> [Accessed 18 May 2011].
- DWIVEDI, P. & BHARADWAJ, K. K. 2013. Effective Trust-aware E-learning Recommender System based on Learning Styles and Knowledge Levels. *Educational Technology & Society*, 16, 201-216.
- DYSPRAXIAFOUNDATION. 2011. *What is Dyspraxia?* [Online]. Available: http://www.dyspraxiafoundation.org.uk/services/dys_dyspraxia.php [Accessed 18 May 2011].
- EFRAIN, J. S., MCNAMEE, S., WARREN, B. & RASKIN, J. D. 2014. Personal Construct Psychology, Radical Constructivism, and Social Constructionism: A Dialogue. *Journal of Constructivist Psychology*, 27, 1-13.
- ELLIS, J., LOGAN, S., PUMPHREY, R., TAN, H. K., HENLEY, W., EDWARDS, V., MOY, R. & GILBERT, R. 2008. Inequalities in provision of the disability living allowance for Down syndrome. *Archives of Disease in Childhood*, 93, 14-16.
- ERTMER, P. A. & NEWBY, T. J. 2013. Behaviorism, Cognitivism, Constructivism: Comparing Critical Features From an Instructional Design Perspective. *Performance Improvement Quarterly*, 26, 43-71.
- FARKAS, C., GOWADIA, V., JAIN, A. & ROY, D. 2005. From XML to RDF: Syntax, semantics, security, and integrity (invited paper). *Security Management, Integrity, and Internal Control in Information Systems*, 193, 41-55.
- FERNANDEZ-LOPEZ, M. & GOMEZ-PEREZ, A. 2002. Overview and analysis of methodologies for building ontologies. *Knowledge Engineering Review*, 17, 129-156.
- FICHTEN, C. S., ASUNCION, J. V., BARILE, M., FERRARO, V. & WOLFORTH, J. 2009a. Accessibility of e-Learning and Computer and Information Technologies for Students with Visual Impairments in Postsecondary Education. *Journal of Visual Impairment & Blindness*, 103, 543-557.
- FICHTEN, C. S., FERRARO, V., ASUNCION, J. V., CHWOJKA, C., BARILE, M., NGUYEN, M. N., KLOMP, R. & WOLFORTH, J. 2009b. Disabilities and e-

References

- Learning Problems and Solutions: An Exploratory Study. *Educational Technology & Society*, 12, 241-256.
- FITRIANIE, S. & ROTHKRANTZ, L. J. M. 2007. An adaptive keyboard with personalized language-based features. *Text, Speech and Dialogue, Proceedings*, 4629, 131-138.
- FLEMING, N. 2001. *VARL: A guide to learning styles* [Online]. Available: <http://www.vark-learn.com/english/index.asp> [Accessed August 17 2014].
- FREI, H. P. & SCHAUBLE, P. 1991. DETERMINING THE EFFECTIVENESS OF RETRIEVAL ALGORITHMS. *Information Processing & Management*, 27, 153-164.
- FREITAS, D. & KOUROUPETROGLOU, G. 2008. Speech technologies for blind and low vision persons. *Technology and Disability*, 20, 135-156.
- GABLE, G. G. 1994. Integrating Case Study and Survey Research Methods: An Example in Information Systems. *European Journal of Information Systems*, 3, 112-126.
- GAO, M., LIU, K. C. & WU, Z. F. 2010. Personalisation in web computing and informatics: Theories, techniques, applications, and future research. *Information Systems Frontiers*, 12, 607-629.
- GARRIGOS, I., MELIA, S. & CASTELEYN, S. 2009. Adapting the Presentation Layer in Rich Internet Applications. *Web Engineering, Proceedings*, 5648, 292-299.
- GASSON, S. 2003. Human-Centered Vs. User-Centered Approaches to Information Systems Design. *The Journal of Information Technology Theory and Application (JITTA)*, 5, 29-46.
- GEVARTER, C., O'REILLY, M. F., ROJESKI, L., SAMMARCO, N., LANG, R., LANCIONI, G. E. & SIGAFOOS, J. 2013. Comparing communication systems for individuals with developmental disabilities: A review of single-case research studies. *Research in Developmental Disabilities*, 34, 4415-4432.
- GHAUTH, K. I. & ABDULLAH, N. A. 2010. Learning materials recommendation using good learners' ratings and content-based filtering. *Etr&D-Educational Technology Research and Development*, 58, 711-727.
- GIL-RODRIGUEZ, E. P., GARRETA-DOMINGO, M., PLANELLA-RIBERA, J., ALMIRALL-HILL, M. & SABATE-JARDI, L. 2006. Usability for all: Towards improving the e-learning experience for visually impaired users. In: MIESENBERGER, K., KLAUS, J., ZAGLER, W. & KARSHMER, A. (eds.) *Computers Helping People with Special Needs, Proceedings*.
- GILLANI, B. & O'GUINN, C. 2004. Cognitive Theories and the Design of E-Learning Environments. *Global Health Informatics Education*. IOS Press.
- GOMES, P., ANTUNES, B., RODRIGUES, L., SANTOS, A., BARBEIRA, J. & CARVALHO, R. 2006. Using Ontologies for eLearning Personalization. *3rd ELearning Conference Computer Science Education*. Coimbra Portugal.
- GOMEZ-PEREZ, A. 2001. Evaluation of Ontologies. *International Journal of Intelligent Systems*, 16, 391-401.
- GOODMAN-DEANE, J., WARD, J., HOSKING, I. & CLARKSON, P. J. 2014. A comparison of methods currently used in inclusive design. *Applied Ergonomics*, 45, 886-894.
- GOUTTE, C. & GAUSSIÉ, E. 2005. A probabilistic interpretation of precision, recall and F-score, with implication for evaluation. *Advances in Information Retrieval*, 3408, 345-359.
- GRANIC, A. & CUKUSIC, M. 2011. Usability Testing and Expert Inspections Complemented by Educational Evaluation: A Case Study of an e-Learning Platform. *Educational Technology & Society*, 14, 107-123.

References

- GREGOR, P., SLOAN, D. & NEWELL, A. F. 2005. Disability and technology: Building barriers or creating opportunities? *Advances in Computers*, Vol 64, 64, 283-346.
- GRUBER, T. 2009. Ontology. *Encyclopedia of Database Systems*. Springer-Verlag.
- GRUBER, T. R. 1993. A TRANSLATION APPROACH TO PORTABLE ONTOLOGY SPECIFICATIONS. *Knowledge Acquisition*, 5, 199-220.
- GRÜNINGER, M. & FOX, M. S. 1995. Methodology for the Design and Evaluation of Ontologies. *IJCAI-95 Workshop on Basic Ontological Issues in Knowledge Sharing*. Montreal.
- GUENAGA, M. L., BURGER, D. & OLIVER, J. 2004. Accessibility for e-Learning environments. *Computers Helping People with Special Needs: Proceedings*, 3118, 157-163.
- GUERRIERI, E. 1998. Software document reuse with XML. *Fifth International Conference on Software Reuse - Proceedings*, 246-254.
- HAGAN, L. & THOMPSON, H. 2014. It's good to talk: developing the communication skills of an adult with an intellectual disability through augmentative and alternative communication. *British Journal of Learning Disabilities*, 42, 66-73.
- HALBERT, C., KRIEBEL, R., CUZZOLINO, R., COUGHLIN, P. & FRESA-DILLON, K. 2011. Self-assessed learning style correlates to use of supplemental learning materials in an online course management system. *Medical Teacher*, 33, 331-333.
- HARTLEY, D., ROCHTCHINA, E., NEWALL, P., GOLDING, M. & MITCHELL, P. 2010. Use of Hearing Aids and Assistive Listening Devices in an Older Australian Population. *Journal of the American Academy of Audiology*, 21, 642-653.
- HELANDER, M., LANDAUER, T. K. & PRABHU, P. V. 1997. *Handbook of human-computer interaction*, Amsterdam ; Oxford, Elsevier.
- HENZE, N., DOLOG, P. & NEJDL, W. 2004. Reasoning and ontologies for personalized e-Learning in the semantic web. *Educational Technology & Society*, 7, 82-97.
- HENZE, N. & HERRLICH, M. 2004. The Personal Reader: A Framework for Enabling Personalization Services on the Semantic Web. *Twelfth GI Workshop on Adaptation and User Modeling in Interactive Systems (ABIS 04)*. Berlin, Germany.
- HESA. 2012. *Students and Qualifiers Data Tables* [Online]. Available: http://www.hesa.ac.uk/index.php?option=com_datatables&Itemid=121&task=show_category&catdex=3 [Accessed 19 March 2012].
- HOLLIER, S. 2007. *The disability divide: a study into the impact of computing and internet-related technologies on people who are blind or vision impaired*. PhD, Curtin University of Technology.
- HONEY, P. & MUMFORD, A. 1992. *The Manual of Learning Styles*, Maidenhead, Peter Honey.
- HOPFGARTNER, F. & JOSE, J. M. 2010. Semantic user profiling techniques for personalised multimedia recommendation. *Multimedia Systems*, 16, 255-274.
- HORNICKEL, J., ZECKER, S. G., BRADLOW, A. R. & KRAUS, N. 2012. Assistive listening devices drive neuroplasticity in children with dyslexia. *Proceedings of the National Academy of Sciences of the United States of America*, 109, 16731-16736.
- HORROCKS, I. 2002. DAML+OIL: A reason-able Web ontology language. *Advances in Database Technology - Edbt 2002*, 2287, 2-13.
- HORROCKS, I. 2008. Ontologies and the Semantic Web. *Communications of the Acm*, 51, 58-67.

References

- HOY, M. B. 2014. EMERGING TECHNOLOGIES. *Medical Reference Services Quarterly*, 33, 85-91.
- HSIEH, T. C., LEE, M. C. & SU, C. Y. 2013. Designing and implementing a personalized remedial learning system for enhancing the programming learning. *Educational Technology & Society*, 16, 32-46.
- HULL, D. 1993. Using statistical testing in the evaluation of retrieval experiments. *16th annual international ACM SIGIR conference on Research and development in information retrieval*. Pittsburgh, Pennsylvania, USA.
- HWANG, C. S., WENG, H. H., WANG, L. F., TSAI, C. H. & CHANG, H. T. 2014. An Eye-Tracking Assistive Device Improves the Quality of Life for ALS Patients and Reduces the Caregivers' Burden. *Journal of Motor Behavior*, 46, 233-238.
- HYPONNEN, H. (ed.) 1999. *The Handbook on Inclusive Design for Telematics Applications*, Siltasaarekatu 18A, 00531 Helsinki, Finland.
- IDA. 2011. *What is Dyslexia?* [Online]. International Dyslexia Association. Available: <http://www.interdys.org/FAQWhatIs.htm> [Accessed May 18 2011].
- IGLESIAS, A., MORENO, L., MARTINEZ, P. & CALVO, R. 2014. Evaluating the accessibility of three open-source learning content management systems: A comparative study. *Computer Applications in Engineering Education*, 22, 320-328.
- JAEGER, P. T. 2006. Assessing Section 508 compliance on federal e-government Web sites: A multi-method , user-centered evaluation of accessibility for persons with disabilities. *Government Information Quarterly*, 23, 169-190.
- JEONG, H. Y. & HONG, B. H. 2013. A service component based CAT system with SCORM for advanced learning effects. *Multimedia Tools and Applications*, 63, 217-226.
- JOHNSON, L., RICKEL, J. & LESTER, J. 2000. Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments. *International Journal of Artificial Intelligence in Education* 11, 47-78.
- JONES, A., SCANLON, E., TOSUNOGLU, C., MORRIS, E., ROSS, S., BUTCHER, P. & GREENBERG, J. 1999. Contexts for evaluating educational software. *Interacting with Computers*, 11, 499-516.
- JONES, A., SCANLON, E., TOSUNOGLU, C., ROSS, S., BUTCHER, P., MURPHY, P. & GREENBERG, J. 1996. Evaluating CAL at the Open University: 15 years on. *Computers & Education*, 26, 5-15.
- JONES, M. G., TAYLOR, A. R. & BROADWELL, B. 2009. Concepts of Scale Held by Students With Visual Impairment. *Journal of Research in Science Teaching*, 46, 506-519.
- JOVANOVIC, J., GASEVIC, D., KNIGHT, C. & RICHARDS, G. 2007. Ontologies for effective use of context in e-learning settings. *Educational Technology & Society*, 10, 47-59.
- JU, B., QIAN, Y. T., YE, M. C., NI, R. & ZHU, C. X. 2015. Using Dynamic Multi-Task Non-Negative Matrix Factorization to Detect the Evolution of User Preferences in Collaborative Filtering. *Plos One*, 10, 20.
- KADOUCHE, R., MOKHTARI, M., GIROUX, S. & ABDULRAZAK, B. 2008. Personalization in Smart Homes for Disabled People. *FgcN: Proceedings of the 2008 Second International Conference on Future Generation Communication and Networking, Vols 1 and 2*, 889-893.
- KALIA, A. A., LEGGE, G. E. & GIUDICE, N. A. 2008. Learning building layouts with non-geometric visual information: The effects of visual impairment and age. *Perception*, 37, 1677-1699.
- KEEN, E. M. 1992. PRESENTING RESULTS OF EXPERIMENTAL RETRIEVAL COMPARISONS. *Information Processing & Management*, 28, 491-502.

References

- KEET, C. M., ALBERTS, R., GERBER, A. & CHIMAMIWA, G. Enhancing web portals with Ontology-Based Data Access: the case study of South Africa's Accessibility Portal for people with disabilities. Fifth International Workshop OWL: Experiences and Directions (OWLED'08), 2008 Karlsruhe, Germany.
- KELLY, S. A. & SMITH, T. J. 2008. The digital social interactions of students with visual impairments: Findings from two national surveys. *Journal of Visual Impairment & Blindness*, 102, 528-539.
- KERLINGER, F. N. 1986. *Foundations of behavioral research*, New York, Holt, Rinehart and Winston.
- KITCHENHAM, B., PICKARD, L. & PFLEEGER, S. L. 1995. Case Studies for Method and Tool Evaluation. *IEEE Software*, 12, 52-62.
- KLASNJA-MILICEVIC, A., VESIN, B., IVANOVIC, M. & BUDIMAC, Z. 2011. E-Learning personalization based on hybrid recommendation strategy and learning style identification. *Computers & Education*, 56, 885-899.
- KLEIN, M. 2002. Interpreting XML documents via an RDF Schema ontology. *13th International Workshop on Database and Expert Systems Applications, Proceedings*, 889-893.
- KNUBLAUCH, H., FERGERSON, R. W., NOY, N. F. & MUSEN, M. A. 2004. The Protege OWL Plugin: An open development environment for Semantic Web applications. *Semantic Web - Iswc 2004, Proceedings*, 3298, 229-243.
- KO, C.-C., CHIANG, C.-H., LIN, Y.-L. & CHEN, M.-C. 2011. An Individualized e-Reading System Developed Based on Multi-representations Approach. *Educational Technology & Society*, 14, 88-98.
- KOGALOVSKY, M. R. 2013. Metadata in computer systems. *Programming and Computer Software*, 39, 182-193.
- KOLB, D. 1985. *Learning Style Inventory*, Boston, MA, McBer and Company.
- KOUROUPETROGLOU, C., SALAMPASIS, M. & MANITSARIS, A. A Semantic-Web based Framework for Developing Applications to Improve Accessibility in the WWW. 2006 international cross-disciplinary workshop on Web accessibility (W4A): Building the mobile web: rediscovering accessibility?, 2006 Edingburgh, UK. 98-108.
- KOUTSABASIS, P. & DARZENTAS, J. 2008. Item-Based Filtering and Semantic Networks for Personalized Web Content Adaptation in E-Commerce. *Artificial Intelligence: Theories, Models and Applications, SETN*, 5138, 148-159.
- KRITIKOU, Y., DEMESTICHAS, P., ADAMOPOULOU, E., DEMESTICHAS, K., THEOLOGOU, M. & PARADIA, M. 2008. User Profile Modeling in the context of web-based learning management systems. *Journal of Network and Computer Applications*, 31, 603-627.
- KYNG, M. 1991. DESIGNING FOR COOPERATION - COOPERATING IN DESIGN. *Communications of the Acm*, 34, 64-73.
- KYUNG NG, C. 2013. Education for all: a disabled-friendly e-learning system. *Journal of Southeast Asian Education*, 1, 139-156.
- LAABIDI, M., JEMNI, M., BEN AYED, L. J., BEN BRAHIM, H. & BEN JEMAA, A. 2014. Learning technologies for people with disabilities. *Journal of King Saud University- Computer and Information Sciences*, 26, 29-45.
- LANCIONI, G. E., SINGH, N. N., O'REILLY, M. F., SIGAFOOS, J., ALBERTI, G., PERILLI, V., LAPORTA, D., CAMPODONICO, F., OLIVA, D. & GROENEWEG, J. 2014a. People with multiple disabilities learn to engage in occupation and work activities with the support of technology-aided programs. *Research in Developmental Disabilities*, 35, 1264-1271.
- LANCIONI, G. E., SINGH, N. N., O'REILLY, M. F., SIGAFOOS, J., BOCCASINI, A., ALBERTI, G. & LANG, R. 2014b. People with Multiple Disabilities Use

References

- Basic Reminding Technology to Engage in Daily Activities at the Appropriate Times. *Journal of Developmental and Physical Disabilities*, 26, 347-355.
- LANGE, A. A., MULHERN, G. & WYLIE, J. 2009. Proofreading Using an Assistive Software Homophone Tool Compensatory and Remedial Effects on the Literacy Skills of Students With Reading Difficulties. *Journal of Learning Disabilities*, 42, 322-335.
- LANGE, D. B. 1996. An Object-Oriented design Method for Hypermedia Information Systems. *Journal of Organizational Computing & Electronic Commerce*, 6.
- LASSILA, O. 1998. Web Metadata: A matter of semantics. *Ieee Internet Computing*, 2, 30-37.
- LATTAL, K. A. 1998. A century of effect: Legacies of E.L. Thorndike's Animal Intelligence monograph. *Journal of the Experimental Analysis of Behavior*, 70, 325-336.
- LEE, A. S. 1989. A SCIENTIFIC METHODOLOGY FOR MIS CASE STUDIES. *Mis Quarterly*, 13, 33-50.
- LEE, J., PHAM, M.-D., LEE, J., HAN, W.-S., CHO, H., YU, H. & LEE, J.-H. 2011. Processing SPARQL queries with regular expressions in RDF databases. *Bmc Bioinformatics*, 12.
- LEE, J. S. & LUCYSZYN, S. 2005. A micromachined refreshable Braille cell. *Journal of Microelectromechanical Systems*, 14, 673-682.
- LEE, S., MURPHY, G. C., FRITZ, T. & ALLEN, M. How can diagramming tools help support programming activities? Proceedings of the 2008 IEEE Symposium on Visual Languages and Human-Centric Computing, 2008 Herrsching am Ammersee. 246-249.
- LENAT, D. B. & GUHA, R. V. 1990. *Building Large knowledge-Based systems*, Addison-Wesley.
- LEWIS, K. O., CIDON, M. J., SETO, T. L., CHEN, H. & MAHAN, J. D. 2014. Leveraging e-Learning in Medical Education. *Current problems in pediatric and adolescent health care*, 44, 150-63.
- LEYPOLD, M. E., NOLTING, K., ROSER, M. & VOIGT, D. 2004. Learner centrism and constructivism - New paradigms for e-learning? *ED-MEDIA 2004: World Conference on Educational Multimedia, Hypermedia & Telecommunications*, Vols. 1-7, 2434-2441.
- LI, Y. Q., JOHNSON, S. & NAM, C. 2011. Haptically Enhanced User Interface to Support Science Learning of Visually Impaired. *Human-Computer Interaction: Users and Applications, Pt Iv*, 6764, 68-76.
- LIANG, T.-P., LI, Y.-W. & TURBAN, E. Personalized services as empathic responses: the role of intimacy. PACIS 2009 Proceedings, 2009. Paper 73.
- LIECHTI, O., SIFER, M. J. & ICHIKAWA, T. 1998. Structured graph format: XML metadata for describing Web site structure. *Computer Networks and Isdn Systems*, 30, 11-21.
- LIGHT, J. & MCNAUGHTON, D. 2014. From Basic to Applied Research to Improve Outcomes for Individuals Who Require Augmentative and Alternative Communication: Potential Contributions of Eye Tracking Research Methods. *Augmentative and Alternative Communication*, 30, 99-105.
- LIN, T.-J. 2011. Moodle 2.0. *Language Learning & Technology*, 15, 27-33.
- LIN, T. C., HO, H. P. & CHANG, C. T. 2014. EVALUATION MODEL FOR APPLYING AN E-LEARNING SYSTEM IN A COURSE: AN ANALYTIC HIERARCHY PROCESS-MULTI-CHOICE GOAL PROGRAMMING APPROACH. *Journal of Educational Computing Research*, 50, 135-157.

References

- LITTLE, S., FERGUSON, R. & RUGER, S. 2012. Finding and reusing learning materials with multimedia similarity search and social networks. *Technology Pedagogy and Education*, 21, 255-271.
- LIU, F., LI, X. Y. & GAO, G. H. Ontology-based personalized recommendation technology research of learning resources. Proceedings of the ETP/IITA Conference on System Science and Simulation in Engineering (SSSE 2010), 2010 Hong Kong. 89-92.
- LONGPRADIT, P., BAILEY, C., HALL, W. & WILLS, G. Personalised navigation system with multidimensional linkbases. Proceedings of the 4th International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, LNCS, 2006. 293-297.
- LONGPRADIT, P., HALL, W., WALTERS, R. J., GILBERT, L., GEE, Q. & WILLS, G. B. 2008. An Inquiry-led Personalised Navigation System (IPNS) using multi-dimensional linkbases. *New Review of Hypermedia and Multimedia*, 14, 33-55.
- LORENZ, M. & HORSTMANN, M. Semantic Access to Graphical Web Resources for Blind Users. 4th International Semantic Web Conference (ISWC 2004), 2004 Hiroshima, Japan.
- LYONS, K., STARNER, T. & GANE, B. 2006. Experimental evaluations of the twiddler one-handed chording mobile keyboard. *Human-Computer Interaction*, 21, 343-392.
- LYTRAS, M., TSILIRA, A. & THEMISTOCLEOUS, M. 2003a. Towards the Semantic E-Learning: An Ontological Oriented Discussion of the New Research Agenda in E-Learning. *Ninth Americas Conference on Information Systems (AMCIS)*.
- LYTRAS, M. D., POILOUDI, A. & KORFIATIS, N. 2003b. An Ontology Oriented Approach on eLearning: Integrating Semantics for Adaptive eLearning Systems. *ECIS 2003*.
- MALONE, J. C. 2014. Did John B. Watson Really "Found" Behaviorism? *Behavior Analyst*, 37, 1-12.
- MANCUSO-MURPHY, J. 2007. Distance education in nursing: An integrated review of online nursing students' experiences with technology delivered instruction. *Journal of Nursing Education*, 46, 252-260.
- MANNING, C. D., RAGHAVAN, P. & SCHÜTZE, H. 2008. *Introduction to Information Retrieval*, Cambridge University Press.
- MARTIN, P. & EKLUND, P. 1999. Embedding knowledge in Web documents. *Computer Networks-the International Journal of Computer and Telecommunications Networking*, 31, 1403-1419.
- MCGUINNESS, D. L. & VAN HARMELEN, F. 2004. *OWL Web Ontology Language Overview* [Online]. Available: <http://www.w3.org/TR/owl-features/> [Accessed January 12, 2015].
- MCINERNEY, M. & WALDEN, P. 2013. Evaluating the Use of an Assistive Listening Device for Communication Efficiency Using the Diapix Task: A Pilot Study. *Folia Phoniatrica Et Logopaedica*, 65, 25-31.
- MCKENZIE, J. 2003. Inspired Investigations. *The Educational Technology Journal*, 12.
- MEEGAR, M. A. & PACIS, D. 2012. A Comparison of Two Theories of Learning -- Behaviorism and Constructivism as applied to Face -to-Face and Online Learning,. *E-Leader*. Manila.
- MILLARD, D., MOREAU, L., DAVIS, H. & REICH, S. 2000. FOHM: A Fundamental Open Hypertext Model for Investigating Interoperability between Hypertext Domains. *Eleventh ACM Conference on Hypertext and Hypermedia HT'00*.
- MIRRI, S., GAY, G. R., SALOMONI, P. & ROCCETTI, M. 2009. Meeting learners' preferences: implementing content adaptability in e-learning. *New Learning Technologies 2009*. Orlando.

References

- MOAZAMI, F., BAHRAMPOUR, E., AZAR, M. R., JAHEDI, F. & MOATTARI, M. 2014. Comparing two methods of education (virtual versus traditional) on learning of Iranian dental students: a post-test only design study. *Bmc Medical Education*, 14, 5.
- MOHAMMED, P. & MOHAN, P. 2006. Incorporating multiple ontologies into the IEEE learning object metadata standard. *Canadian Semantic Web*, 2, 143-154.
- MOHAN, P. & BROOKS, C. 2003. Learning objects on the Semantic Web. *3rd Ieee International Conference on Advanced Learning Technologies, Proceedings*, 195-199.
- MOLDOVAN, A. N. & MUNTEAN, C. H. 2009. Personalisation of the Multimedia Content Delivered to Mobile Device Users. *Bmsb: 2009 Ieee International Symposium on Broadband Multimedia Systems and Broadcasting, Vols 1 and 2*, 209-214.
- MONACHESI, P., SIMOV, K., MOSSEL, E., OSENOVA, P. & LEMNITZER, L. 2008. What ontologies can do for eLearning. *International Conference on Interactive Mobile and Computer Aided Learning, IMCL08*. Amman, Jordan.
- MOR, E. & MINGUILLON, J. E-learning personalization based on itineraries and long-term navigational behavior. *Proceedings on the 13th International World Wide Web conference*, 2004 New York, USA. 264-265.
- MORENO, L., MARTINEZ, P., CONTRERAS, J. & BENJAMINS, R. Towards Accessible Semantic Web Applications. *International Conference on Dublin Core and Metadata Applications: Vocabularies in Practice*, 2005.
- MULLER, M. J. 1996. Defining and designing the Internet - Participation by Internet stakeholder constituencies. *Social Science Computer Review*, 14, 30-33.
- MULLER, M. J. & KUHN, S. 1993. ASPECTS OF PARTICIPATORY DESIGN - RESPONSE. *Communications of the Acm*, 36, 18-&.
- MULLER, P., VANENGELLEN, J., TERLOUW, P., DEVREEDE, G. J. & IEEE IND ELECTR, S. O. C. 1996. *Multimedia and co-operative work in new product development: A participatory approach to virtual prototyping*.
- MÖDRITSCHER, F. 2006. e-Learning Theories in Practice: A Comparison of three Methods. *Journal of Universal Science and Technology of Learning*, 3-18.
- NADOLSKI, R. J., VAN DEN BERG, B., BERLANGA, A. J., DRACHSLER, H., HUMMEL, H. G. K., KOPER, R. & SLOEP, P. B. 2009. Simulating Light-Weight Personalised Recommender Systems in Learning Networks: a Case for Pedagogy-Oriented and Rating-Based Hybrid Recommendation Strategies. *Journal of Artificial Societies and Social Simulation*, 12.
- NAPHADE, M. R. & HUANG, T. S. 2001. A probabilistic framework for semantic video indexing, filtering, and retrieval. *Ieee Transactions on Multimedia*, 3, 141-151.
- NASRAOUI, O. & ZHUHADAR, L. 2010. Improving Recall and Precision of a Personalized Semantic Search Engine for E-learning. *Fourth International Conference on Digital Society: Icds 2010, Proceedings*, 216-221.
- NEDUNGADI, P. & RAMAN, R. 2012. A new approach to personalization: integrating e-learning and m-learning. *Etr&D-Educational Technology Research and Development*, 60, 659-678.
- NEVILE, L. & TREVIRANUS, J. 2006. Interoperability for Individual Learner Centred Accessibility for Web-based Educational Systems. *Educational Technology & Society*, 9, 215-227.
- NEWELL, A. F. & GREGOR, P. 2000. "User Sensitive Inclusive Design" - in search of a new paradigm. *Cuu 2000 Conference Proceedings*, 39-44.
- NEWELL, A. F., GREGOR, P., MORGAN, M., PULLIN, G. & MACAULAY, C. 2010. User-Sensitive Inclusive Design. *Univ Access Inf Soc*, 9.

References

- NEWELL, A. F., GREGOR, P., MORGAN, M., PULLIN, G. & MACAULAY, C. 2011. User-Sensitive Inclusive Design. *Universal Access in the Information Society*, 10, 235-243.
- NGANJI, J. & BRAYSHAW, M. 2011. Towards An Ontology-Based Community of Agents for Personalisation of Services for Disabled Students. *IADIS Interfaces and Human Computer Interaction*. Rome, Italy: IADIS.
- NGANJI, J., BRAYSHAW, M. & TOMPSETT, B. 2011. Ontology-Based E-Learning Personalisation for Disabled Students in Higher Education. *ITALICS*, 10, 1-11.
- NGANJI, J. T., BRAYSHAW, M. & TOMPSETT, B. 2013a. Describing and Assessing Image Descriptions for Visually Impaired Web Users with IDAT. *Advances in Intelligent Systems and Computing*, 179, 27-37.
- NGANJI, J. T., BRAYSHAW, M. & TOMPSETT, B. 2013b. Ontology-driven disability-aware e-learning personalisation with ONTODAPS. *Campus-Wide Information Systems*, 30, 17-34.
- NGANJI, J. T., KWEMAIN, R. & TAKU, C. A. 2010. Closing the digital gap in Cameroonian secondary schools through the CIAC project. *International Journal of Education and Development using Information and Communication Technology(IJEDICT)*, 6, 106-114.
- NGANJI, J. T. & NGGADA, S. H. 2011. Disability-Aware Software Engineering for Improved System Accessibility and Usability. *International Journal of Software Engineering and Its Applications (IJSEIA)*, 5, 47-62.
- NGANJI, J. T. & NGGADA, S. H. 2014. Adoption of Blended Learning Technologies in Selected Secondary Schools in Cameroon and Nigeria: Challenges in Disability Inclusion. In: OLULUBE, N. (ed.) *Advancing Technology and Educational Development through Blended Learning in Emerging Economies*. Hershey, PA: Information Science Reference.
- NIARAKI, A. S. & KIM, K. 2009. Ontology based personalized route planning system using a multi-criteria decision making approach. *Expert Systems with Applications*, 36, 2250-2259.
- NIELSEN, J. 1993. *Usability engineering*, Boston ; London, Academic Press.
- NIELSEN, J. 1994. Usability inspection methods. In: NIELSEN, J. & MACK, R. (eds.) *Usability Inspection Methods*. New York: John Wiley.
- NIELSEN, J. 2005. *Heuristic Evaluation* [Online]. Available: <http://www.useit.com/papers/heuristic/> [Accessed 10 August 2011].
- NIELSEN, J. 2012. *Usability 101: Introduction to Usability* [Online]. Available: <http://www.nngroup.com/articles/usability-101-introduction-to-usability/> [Accessed February 22, 2015].
- NORMAN, D. A. 1988. *The psychology of everyday things*, New York, Basic Books.
- NORTON, M. & TREVIRANUS, J. 2003. *IMS learner information package accessibility for LIP best practice and implementation guide* [Online]. Available: http://www.imsglobal.org/accessibility/acclipv1p0/imsacclip_infov1p0.html [Accessed January 13, 2015].
- NYHOF-YOUNG, J., WALSH, L. & STEWART, P. 2002. Let's Ask the Users! Development and Implementation of an Evaluation Strategy for Multimedia Teaching Software. *International Slice of Life Conference*. University of Toronto, ON.
- OCHOA, X., KLERKX, J., VANDEPUTTE, B. & DUVAL, E. 2011. On the Use of Learning Object Metadata: The GLOBE Experience. *Towards Ubiquitous Learning, Ec-Tel 2011*, 6964, 271-284.

References

- OHARE, M. 1993. TALK AND CHALK - THE BLACKBOARD AS AN INTELLECTUAL TOOL. *Journal of Policy Analysis and Management*, 12, 238-246.
- OHENE-DJAN, J. & SHIPSEY, R. 2008. Principles for inclusive software design of learning technologies. *8th Ieee International Conference on Advanced Learning Technologies, Proceedings*, 989-990.
- OLLA, P. & CHOUDRIE, J. 2014. Mobile technology utilization for social development in developing countries: An ethnographic futures research study. *Information Systems Frontiers*, 16, 369-382.
- ORLANDER, J. D. 2007. Twelve Tips for use of a white board in clinical teaching: Reviving the chalk talk. *Medical Teacher*, 29, 89-92.
- OZKAN, S. Y., ONCUL, N. & KAYA, O. 2013. Effects of Computer-Based Instruction on Teaching Emergency Telephone Numbers to Students with Intellectual Disability. *Education and Training in Autism and Developmental Disabilities*, 48, 200-217.
- PAH, I., STOICA, F., CACOVEAN, L. F. & POPA, E. M. 2008. Using Ontology in Electronic Evaluation for Personalization of eLearning Systems. *Proceedings of the 8th Wseas International Conference on Applied Informatics and Communications, Pts I and II*, 332-337.
- PAHL, C. 2003. Managing evolution and change in web-based teaching and learning environments. *Computers & Education*, 40, 99-114.
- PAIREEKRENG, W. & WONG, K. W. 2010. Mobile Content Personalisation Using Intelligent User Profile Approach. *Third International Conference on Knowledge Discovery and Data Mining: Wkdd 2010, Proceedings*, 241-244.
- PAPERT, S. 1980. *Mindstorms: Children, Computers and Powerful Ideas*, New York, Basic Books.
- PAVLOV, I. P. 1902. *The Work Of The Digestive Glands* London, Griffin.
- PEARSON, E., GKATZIDOU, V. & GREEN, S. 2009. A proposal for an adaptable personal learning environment to support learners' needs and preferences. *ascilite Auckland 2009*.
- PETER, S. E., BACON, E. & DASTBAZ, M. 2010. Adaptable, personalised e-learning incorporating learning styles. *Campus Wide Information Systems*, 27, 91-100.
- PETRIE, H., HAMILTON, F., KING, N. & PAVAN, P. 2006. Remote Usability Evaluations with Disabled People. *SIGCHI conference on Human Factors in computing systems*. Montreal, Quebec, Canada: ACM.
- PETRIE, H., HARRISON, C. & DEV, S. Describing images on the web: a survey of current practice and prospects for the future. *Proceedings of the 3rd International Conference on Universal Access in Human-Computer Interaction*, 2005 Las Vegas, Nevada. Lawrence Erlbaum Associates.
- PI-HUA, T. 2006. Bridging pedagogy and technology: User evaluation of pronunciation oriented CALL software. *Australasian Journal of Educational Technology*, 22, 375-397.
- PIAGET, J. 1973. *The Child's Conception of the World*, London, Paladin.
- POORE-PARISEAU, C. 2010. Online Learning: Designing for All Users. *Journal of Usability Studies*, 5, 147-156
- POVEDA-VILLALON, M., GOMEZ-PEREZ, A. & SUAREZ-FIGUEROA, M. C. 2014. OOPS! (OntOlogy Pitfall Scanner!): An On-line Tool for Ontology Evaluation. *International Journal on Semantic Web and Information Systems*, 10, 7-34.
- POWER, C. & PAIGE, R. 2009. Content Personalization for Inclusive Education through Model-Driven Engineering. *Universal Access in Human-Computer Interaction: Applications and Services, Pt Iii*, 5616, 102-109.

References

- POWER, C., PETRIE, H., SAKHAROV, V. & SWALLOW, D. 2010. Virtual Learning Environments: Another Barrier to Blended and E-Learning. *Computers Helping People with Special Needs, Proceedings, Pt 1*, 6179, 519-526.
- PUKKHEM, N. & VATANAWOOD, W. 2011. Personalised learning object based on multi-agent model and learners' learning styles. *Maejo International Journal of Science and Technology*, 5, 292-311.
- QUEST, D. J., LAND, M. L., BRETTIN, T. S. & COTTINGHAM, R. W. 2010. Next generation models for storage and representation of microbial biological annotation. *Bmc Bioinformatics*, 11.
- QUINN, C. N. 1996. Pragmatic evaluation: lessons from usability. In: CHRISTIE, A. & VAUGHAN, B. (eds.) *13th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (ASCILITE 96)*. Adelaide: Uni SA: Australia Society for Computers in Learning in Tertiary Education.
- RASKIN, J. D. 2002. Constructivism in psychology: Personal construct psychology, radical constructivism, and social constructionism. *Studies in Meaning: Exploring Constructivist Psychology*, 1-25.
- RAVENSCROFT, A. 2001. Designing E-learning Interactions in the 21st Century: revisiting and rethinking the role of theory. *European Journal of Education*, 36, 133-156.
- RECKER, M. M. & WILEY, D. A. 2001. A Non-authoritative Educational Metadata Ontology for Filtering and Recommending Learning Objects. *Interactive Learning Environments*, 9, 255-271.
- REFORMAT, M. Z. & GOLMOHAMMADI, S. K. 2010. Rule- and OWA-based Semantic Similarity for User Profiling. *International Journal of Fuzzy Systems*, 12, 87-102.
- REY, G. D. & STEIB, N. 2013. The personalization effect in multimedia learning: The influence of dialect. *Computers in Human Behavior*, 29, 2022-2028.
- RIX, J. 2009. A model of simplification: the ways in which teachers simplify learning materials. *Educational Studies*, 35, 95-106.
- ROBERTSON, S. I. 2014. Academic essay writing as imitative problem solving: examples from distance learning. *Assessment & Evaluation in Higher Education*, 39, 263-274.
- ROCKLEY, A., MANNING, S. & STC 2002. E-learning, single sourcing and SCORM. *Stc's 49th Annual Conference, Proceedings: Leading the Technical Communication Revolution*, 108-110.
- ROSS, J. A., SIBBALD, T. & BRUCE, C. D. 2009. Characteristics of students assigned to technology-based instruction. *Journal of Computer Assisted Learning*, 25, 562-573.
- ROY, D., SARKAR, S. & GHOSE, S. 2009. A Personalized Information Retrieval Module for Retrieving Learning Materials. *2009 International Workshop on Technology for Education (T4e 2009)*, 68-74.
- RUANO-RUANO, I., GOMEZ-ORTEGA, J., GAMEZ-GARCIA, J., ESTEVEZ-ESTEVEZ, E. & IEEE. 2013. Integration of Online Laboratories-LMS via SCORM. *IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, Oct 13-16 2013 Manchester, ENGLAND. NEW YORK: Ieee, 3163-3167.
- RZEPA, H. S. & WILLIGHAGEN, E. L. 2008. CHED 760-FOAF (Friend-of-a-friend): RDF-metadata enhanced social networking in chemistry. *Abstracts of Papers of the American Chemical Society*, 235.
- SADECK, O. 2013. An Exploration of e-Learning Practices of Teachers at Selected Schools. *8th International Conference on E-Learning*, Jun 27-28 2013 Cape Town, SOUTH AFRICA. NR READING: Acad Conferences Ltd, 519-522.

References

- SALAMPASIS, M., KOUROUPETROGLOU, C. & MANITSARIS, A. Semantically enhanced browsing for blind people in the WWW. Proceedings of the sixteenth ACM conference on Hypertext and hypermedia, 2005 Salzburg, Austria. ACM, New York, 32-34.
- SALEHI, M. & KAMALABADI, I. N. 2013. Hybrid recommendation approach for learning material based on sequential pattern of the accessed material and the learner's preference tree. *Knowledge-Based Systems*, 48, 57-69.
- SALTON, G. 1992. THE STATE OF RETRIEVAL-SYSTEM EVALUATION. *Information Processing & Management*, 28, 441-449.
- SAMPSON, D. G., LYTRAS, M. D., WAGNER, G. & DIAZ, P. 2004. Ontologies and the Semantic Web for e-learning. *Educational Technology & Society*, 7, 26-28.
- SAMPSON, D. G. & ZERVAS, P. 2011. Supporting Accessible Technology-Enhanced Training: The eAccess2Learn Framework. *Ieee Transactions on Learning Technologies*, 4, 353-364.
- SAMPSON, D. G., ZERVAS, P. & CHLOROS, G. 2012. Supporting the Process of Developing and Managing LOM Application Profiles: The ASK-LOM-AP Tool. *Ieee Transactions on Learning Technologies*, 5, 238-250.
- SANCHO, P., MARTINEZ, I. & FERNANDEZ-MANJON, B. 2005. Semantic Web technologies applied to e-learning personalization in (e-aula). *Journal of Universal Computer Science*, 11, 1470-1481.
- SANGUINO, T. J. M., HERNANDEZ, F. A. M. & LOPEZ, C. S. 2014. Evaluating a computer-based simulation program to support wireless network fundamentals. *Computers & Education*, 70, 233-244.
- SCHEWE, K. D., THALHEIM, B. & WANG, Q. 2009. Customising Web Information Systems According to User Preferences. *World Wide Web-Information and Web Information Systems*, 12, 27-50.
- SCHLEYER, T. K. L. & JOHNSON, L. A. 2003. Evaluation of educational software. *Journal of dental education*, 67, 1221-8.
- SCHMID, H. A. & DONNERHAK, O. 2005. OOHDMDA - An MDA approach for OOHDMD. *Web Engineering, Proceedings*, 3579, 569-574.
- SCHMID, H. A. & HERFORT, O. 2004. A behavioral semantics of OOHDMD core features and of its business process extension. *Web Engineering, Proceedings*, 3140, 74-87.
- SCHMIDT, A. & SCHNEIDER, M. Adaptive Reading Assistance for Dyslexic Students: Closing the Loop. Proceedings of the 15th Workshop on Adaptivity and User Modeling in Interactive Systems, 2007 Halle.
- SCHONER, V., BUZZA, D., HARRIGAN, K. & STRAMPEL, K. 2005. Learning objects in use: 'Lite' assessment for field studies. *Journal of Online Learning and Teaching*, 1, 1-18.
- SCHWABE, D., ROSSI, G. & BARBOSA, S. D. J. 1996. Systematic Hypermedia Application Design with OOHDMD. *ACM International Conference on Hypertext (Hypertext '96)*. Washington DC, USA.
- SEALE, J. 2009. A Contextualised Model for Accessible E-Learning in Higher Education: Understanding the Students' Perspective. *Universal Access in Human-Computer Interaction: Applications and Services, Pt Iii*, 5616, 120-129.
- SEALE, J. & COOPER, M. 2010. E-learning and accessibility: An exploration of the potential role of generic pedagogical tools. *Computers & Education*, 54, 1107-1116.
- SEOK, S., DACOSTA, B., KINSELL, C., POGGIO, J. C. & MEYEN, E. L. 2010. Computer-Mediated Intersensory Learning Model for Students with Learning Disabilities. *TechTrends*, 54, 63-71.
- SEVERANCE, C. 2013. MOOCs: An Insider's View. *Computer*, 46, 93-96.

References

- SHAIKH, Z. A. & KHOJA, S. A. 2014. Personal learning environments and university teacher roles explored using Delphi. *Australasian Journal of Educational Technology*, 30, 202-226.
- SHANI, G. & GUNAWARDANA, A. 2011. Evaluating recommendation systems. In: RICCI, F., ROKACH, L., SHAPIRA, B. & KANTOR, P. (eds.) *Recommender systems handbook*. Berlin: Springer.
- SHEA, P. & BIDJERANO, T. 2014. Does online learning impede degree completion? A national study of community college students. *Computers & Education*, 75, 103-111.
- SHIH, C.-H. 2014. Assisting people with multiple disabilities to improve computer typing efficiency through a mouse wheel and On-Screen Keyboard software. *Research in developmental disabilities*, 35, 2129-36.
- SITZMANN, T., BELL, B. S., KRAIGER, K. & KANAR, A. M. 2009. A MULTILEVEL ANALYSIS OF THE EFFECT OF PROMPTING SELF-REGULATION IN TECHNOLOGY-DELIVERED INSTRUCTION. *Personnel Psychology*, 62, 697-734.
- SKINNER, B. F. 1938. *The Behavior of Organisms: An Experimental Analysis*, New York, Appleton-Century-Crofts.
- SKINNER, B. F. 1974. *About behaviorism* New York, NY, Vintage Books.
- SNOWLING, M. J. 2001. *Dyslexia*, Blackwell, Oxford.
- SQUIRES, D. & PREECE, J. 1999. Predicting quality in educational software: Evaluating for learning, usability and the synergy between them. *Interacting with Computers*, 11, 467-483.
- STEYAERT, J. 2005. Web-based higher education: the inclusion/exclusion paradox. *Journal of Technology in Human Services*, 23, 67-78.
- STOJANOVIC, L., STAAB, S. & STUDER, R. 2001. eLearning based on the Semantic Web. *World Conference on the WWW and the Internet (WebNet 2001)*. Orlando, USA.
- SUGIMOTO, S., BAKER, T. & WEIBEL, S. L. 2002. Dublin Core: Process and principles. *Digital Libraries: People, Knowledge, and Technology, Proceedings*, 2555, 25-35.
- SUMI, K., SUMI, Y., MAS, K., NAKASUKA, S.-I. & HORI, K. 2000. Information Presentation by Inferring User's Interests Based on Individual Conceptual Spaces. *Systems and Computers In Japan*, 31, 1634-1644.
- SUMI, K., SUMI, Y., MASE, K., NAKASUKA, S.-I. & HORI, K. Takealook: Personalizing Information Presentation According to User's Interest Space. *IEEE International Conference on Systems, Man and Cybernetics*, 1999. 354-359.
- TEXTHELP. 2014. *Read&Write Solutions* [Online]. Available: <http://www.texthelp.com/North-America/readwrite-family> [Accessed September 6, 2014 2014].
- THALMANN, S. 2014. Adaptation criteria for the personalised delivery of learning materials: A multi-stage empirical investigation. *Australasian Journal of Educational Technology*, 30, 45-60.
- THOMAS, A., MENON, A., BORUFF, J., RODRIGUEZ, A. M. & AHMED, S. 2014. Applications of social constructivist learning theories in knowledge translation for healthcare professionals: a scoping review. *Implementation Science*, 9, 20.
- THOMS, B. & ERYILMAZ, E. 2014. How media choice affects learner interactions in distance learning classes. *Computers & Education*, 75, 112-126.
- TOMPSETT, B. 2008. Experiencias de enseñanza a estudiantes de informática con discapacidad en universidades del reino unido. *Technologías de la Información Y las Comunicaciones en la Autonomía Personal, Dependencia Y Accesibilidad*,

References

- Fundación Alfredo Brañas, Colección Informática. Colección Informática ed. Santiago de Compostela: Fundación Alfredo Brañas.*
- TREVIRANUS, J. & ROBERTS, V. 2008. Meeting the Learning Needs of all Learners Through IT. *Springer International Handbook of Information Technology in Primary and Secondary Education*.
- TVAROZEK, M., BARLA, M. & BIELIKOVA, M. 2007. Personalized presentation in web-based information systems. *SOFSEM 2007: Theory and Practice of Computer Science, Proceedings*, 4362, 796-807.
- TZOUVELI, P., MYLONAS, P. & KOLLIAS, S. 2008a. An intelligent e-learning system based on learner profiling and learning resources adaptation. *Computers & Education*, 51, 224-238.
- TZOUVELI, P., SCHMIDT, A., SCHNEIDER, M., SYMVONIS, A. & KOLLIAS, S. Adaptive Reading Assistance for the Inclusion of Learners with Dyslexia: The AGENT-DYSL approach. *IEEE Conference on Advanced Learning Technologies (ICALT 08)*, 2008b.
- USCHOLD, M. & KING, M. 1995. Methodology for Building Ontologies. *Workshop on Basic Ontological Issues in Knowledge Sharing*
- VALLET, D., MYLONAS, P., CORELLA, M. A., FUENTES, J. M., CASTELLS, P. & AVRITHIS, Y. A Semantically-Enhanced Personalization Framework for Knowledge-Driven Media Services. *IADIS International Conference on WWW/Internet*, 2005 Lisbon-Portugal.
- VALTONEN, T., HACKLIN, S., DILLON, P., VESISENAHO, M., KUKKONEN, J. & HIETANEN, A. 2012. Perspectives on personal learning environments held by vocational students. *Computers & Education*, 58, 732-739.
- VAN DIJK, J. 1983. Effect of vision on development of multiply handicapped children. *Acta ophthalmologica. Supplementum*, 157, 91-7.
- VARGAS-VERA, M. & LYTRAS, M. 2008. Personalized learning using Ontologies and semantic web technologies. *Emerging Technologies and Information Systems for the Knowledge Society, Proceedings*, 5288, 177-186.
- VASCONCELOS, N. & LIPPMAN, A. 1998. Embedded mixture modeling for efficient probabilistic content-based indexing and retrieval. *Multimedia Storage and Archiving Systems Iii*, 3527, 134-143.
- VERMEULEN, M., VAN ACKER, F., KREIJNS, K. & VAN BUUREN, H. 2012. Teachers and the use of digital learning materials in their educational practices. *Pedagogische Studien*, 89, 159-173.
- VIDAL-VERDU, F. & HAFEZ, M. 2007. Graphical tactile displays for visually-impaired people. *Ieee Transactions on Neural Systems and Rehabilitation Engineering*, 15, 119-130.
- VYGOTSKY, L. 1962. *Thought and Language*, Cambridge, MA, Harvard University Press.
- VYGOTSKY, L. S. 1978. *Mind in society*, Harvard University Press, Cambridge.
- WALL, P. S. & SARVER, L. 2003. Disabled student access in an era of technology. *Internet and Higher Education*, 6, 277-284.
- WALLER, S., BRADLEY, M., HOSKING, I. & CLARKSON, P. J. 2015. Making the case for inclusive design. *Applied ergonomics*, 46 Pt B, 297-303.
- WANG, T. H. 2011. Developing Web-based assessment strategies for facilitating junior high school students to perform self-regulated learning in an e-Learning environment. *Computers & Education*, 57, 1801-1812.
- WANG, T. H. 2014. Developing an assessment-centered e-Learning system for improving student learning effectiveness. *Computers & Education*, 73, 189-203.
- WATSON, J. 1913. Psychology as the Behaviorist Views it. *Psychological Review*, 20, 158-177.

References

- WATSON, J. B. 1930. *Behaviorism*.
- WEN, L. 2008. Flexible Virtual Learning Environments: A Schema-Driven Approach Using Semantic Web Concepts. Hull: University of Hull.
- WEN, L. & BRAYSHAW, M. 2007. An Individualized E-Learning Web Services Prototype. *International Journal of System and Information Sciences Notes*, 1, 29-33.
- WEN, L. & JESSHOPE, C. A General Learning Management System Based on Schema-driven Methodology. Proceedings of the IEEE International Conference on Advanced Learning Technologies (ICALT'04), 2004 Joensuu, Finland. 633-635.
- WENG, P. L., MAEDA, Y. & BOUCK, E. C. 2014. Effectiveness of Cognitive Skills-Based Computer-Assisted Instruction for Students With Disabilities A Synthesis. *Remedial and Special Education*, 35, 167-180.
- WILLIAMS, D. R., KORI, S. K., WILLIAMS, B., SACKRISON, S. J., KOWALSKI, H. M., MCLAUGHLIN, M. G. & KUSZYK, B. S. 2013. JOURNAL CLUB: Voice Recognition Dictation: Analysis of Report Volume and Use of the Send-to-Editor Function. *American Journal of Roentgenology*, 201, 1069-1074.
- WONG, A. A. & BROWN, R. E. 2013. Prevention of vision loss protects against age-related impairment in learning and memory performance in DBA/2J mice. *Frontiers in Aging Neuroscience*, 5, 11.
- WYATT, H. V. 1977. IN DEFENCE OF CHALK AND COLORFUL TALK. *Journal of Biological Education*, 11, 241-241.
- YANG, C.-S. & WEI, C.-P. 2008. *Collaborative Filtering-based Context-Aware Document-Clustering (CF-CAC) Technique*.
- YANG, X. & ALLAN, R. 2007. From e-Learning to e-Research: Building collaborative virtual research environments using Sakai. *DCABES 2007 Proceedings, Vols I and II*, 995-999.
- YIN, R. K. 1984. *Case Study Research Design and Methods*, Beverly Hills, California, Sage Publications.
- YOBAS, L., DURAND, D. M., SKEBE, G. G., LISY, F. J. & HUFF, M. A. 2003. A novel integrable microvalve for refreshable Braille display system. *Journal of Microelectromechanical Systems*, 12, 252-263.
- ZERVAS, P. & SAMPSON, D. G. 2014. The effect of users' tagging motivation on the enlargement of digital educational resources metadata. *Computers in Human Behavior*, 32, 292-300.
- ZHANG, D. S., ZHOU, L. N., BRIGGS, R. O. & NUNAMAKER, J. F. 2006. Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. *Information & Management*, 43, 15-27.
- ZHANG, R. & GUAN, L. 2009. A COLLABORATIVE BAYESIAN IMAGE RETRIEVAL FRAMEWORK. *2009 Ieee International Conference on Acoustics, Speech, and Signal Processing, Vols 1- 8, Proceedings*, 1953-1956.
- ZHAO, Z., RAU, P.-L. P., ZHANG, T. & SALVENDY, G. 2009. Visual search-based design and evaluation of screen magnifiers for older and visually impaired users. *International Journal of Human-Computer Studies*, 67.
- ZHUHADAR, L., NASRAOUI, O. & SOCIETY, I. C. 2008. Semantic Information Retrieval for Personalized E-learning. 20th IEEE International Conference on Tools with Artificial Intelligence, Nov 03-05 2008 Dayton, OH. LOS ALAMITOS: Ieee Computer Soc, 364-368.
- ZUO, Z. H. & ZHOU, M. T. 2003. Web ontology language OWL and its description logic foundation. *Parallel and Distributed Computing, Applications and Technologies, Pdcat'2003, Proceedings*, 157-160.

Appendix A: Consent Forms

Consent Form - Students

Title of the study: Personalizing Learning Resources for Students with Disabilities

Researcher contact information:

Julius Tanyu Nganji
Department of Computer Science
Faculty of Science
University of Hull
Cottingham Road, Hull
HU6 7RX, United Kingdom
Tel: 613-562-5800 ext 2700
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Supervisor contact information:

Dr. Mike Brayshaw
Department of Computer Science
Faculty of Science
University of Hull
Cottingham Road, Hull
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Tel: +44 (0)1482 465976
Email: M.Brayshaw@hull.ac.uk

Invitation to Participate: I am invited to participate in the above mentioned research study conducted by Julius T. Nganji.

Purpose of the Study: The purpose of the study is to personalize learning materials to meet the needs of students with disabilities in an e-learning environment.

Participation: My participation will consist essentially of interacting with an e-learning system and evaluating it which is expected to last between 45-60 minutes during which I will access a tutorial about the learning system, retrieve learning materials from a repository through search and by using the e-learning system. The session has been scheduled for (*place, date and time of each session*). I will also be asked to complete questionnaires.

Benefits: My participation in this study will help towards developing e-learning systems that support learning for students with disabilities and will improve literature on designing e-learning systems for the benefit of students with disabilities.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the contents will be used only for recruitment and scheduling purposes and that my confidentiality will be protected by not publishing any personal information.

Anonymity will be protected in the following manner, if any of my comments are quoted, my name will not be published. My identity will not be revealed in any publication.

Conservation of data: The data collected through hard copies or electronic copies of questionnaires will be kept in a secure manner by locking it in a cabinet or stored in a password protected format in a secure office and only accessed by the researcher for a duration of 5 years.

Compensation: There will be no compensation for participating in this study.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will not be used for this study and will be destroyed.

Acceptance: I, _____, agree to participate in the above research study conducted by Julius T. Nganji of the Department of Computer Science, Faculty of Science, University of Hull, UK, which research is under the supervision of Dr. Mike Brayshaw.

If I have any questions about the study, I may contact the researcher or his supervisor.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5
Tel.: (613) 562-5387
Email: ethics@uottawa.ca

There are two copies of the consent form, one of which is mine to keep.

Participant's signature:

Date:

Researcher's signature:

Date:

Formulaire de consentement - Étudiants

Titre du projet: *Personnalisation de ressources d'apprentissage pour les étudiants en situation de handicap*

Chercheur:

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Email: M.Brayshaw@hull.ac.uk

Invitation à participer: Je suis invité(e) à participer à la recherche nommée ci haut qui est menée par Julius Tanyu Nganji dans le cadre de sa thèse de doctorat, sous la supervision du professeur Brayshaw.

But de l'étude: Le but de l'étude est de personnaliser les matériaux d'apprentissage pour répondre aux besoins des étudiants en situation de handicap dans un environnement d'apprentissage électronique.

Participation: Ma participation consistera essentiellement à interagir avec un système d'apprentissage électronique et l'évaluer, qui devrait durer entre 45-60 minutes au cours de laquelle je vais accéder à un tutoriel sur le système d'apprentissage, récupérer des matériaux d'apprentissage à partir d'un système et en utilisant le système d'apprentissage électronique. La session a été prévue pour le (*lieu, date et heure de chaque session*). Je vais également remplir des questionnaires.

Bienfaits: Ma participation à cette recherche aura pour effet d'élaborer des systèmes d'apprentissage électroniques qui appuient l'apprentissage pour les étudiants en situation de handicap et permettront d'améliorer la littérature sur la conception de systèmes d'apprentissage électroniques pour le bénéfice des étudiants en situation de handicap.

Confidentialité et anonymat: J'ai l'assurance du chercheur que l'information que je partagerai avec lui restera strictement confidentielle. Je comprends que le contenu des données recueillies seront utilisées pour la thèse et les publications à venir, et la conception / mise en œuvre du logiciel et que ma confidentialité sera protégée en ne publiant aucune information personnelle.

L'anonymat est garanti de la façon suivante, si l'un de mes commentaires est cité, mon nom ne sera pas publié. Mon identité ne sera pas révélée dans les publications.

Conservation des données: Les données recueillies grâce à des copies papier ou des copies électroniques des questionnaires seront conservées de façon sécuritaire en les verrouillant dans une armoire ou stockées dans un format protégé par mot de passe dans un bureau sécurisé et uniquement accessibles par le chercheur pour une durée de 5 ans.

Compensation: Il n'y aura pas de compensation pour participer à cette étude.

Participation volontaire: Ma participation à la recherche est volontaire et je suis libre de me retirer en tout temps, et/ou refuser de répondre à certaines questions, sans subir de conséquences négatives. Si je choisis de me retirer de l'étude, les données recueillies jusqu'à ce moment ne seront pas utilisées pour cette étude et seront détruites.

Acceptation: Je _____, accepte de participer à cette recherche menée par Julius T. Nganji de Department of Computer Science, Faculty of Science, University of Hull, UK, laquelle est supervisée par Dr. Mike Brayshaw.

Pour tout renseignement additionnel concernant cette étude, je peux communiquer avec le chercheur ou son superviseur.

Pour tout renseignement sur les aspects éthiques de cette recherche, je peux m'adresser au Responsable de l'éthique en recherche, Université d'Ottawa, Pavillon Tabaret, 550, rue Cumberland, pièce 154, (613) 562-5387 ou ethics@uottawa.ca.

Il y a deux copies du formulaire de consentement, dont une copie que je peux garder.

Signature du participant:

Date:

Signature du chercheur:

Date:

Appendix B: Email Invitation

Email Invitation - Students

Subject: Invitation to participate in a research project on Personalizing Learning Resources for Students with Disabilities.

Dear Sir or Madam,

My name is Julius Tanyu Nganji and I am a PhD student in the Department of Computer Science, Faculty of Science at the University of Hull, UK. I am working on a research project under the supervision of Dr. Mike Brayshaw.

I am writing to you today to invite you to participate in a study entitled “Personalizing Learning Resources for Students with Disabilities”. This study aims to facilitate access to learning materials for students with disabilities in an e-learning environment.

Only students with the following disabilities will participate in this study: Low vision, hearing impairment and dyslexia. As the software is entirely in English, the evaluation and questionnaires will be in English. Selection for this study will be on a first-come, first-served basis. The deadline for participation in this study is December 15, 2014.

This study involves one 45-60 minute experiment that will take place in one of the study rooms at the University of Ottawa. During this time, you will interact with an e-learning software on a computer, carryout some tasks and then fill some questionnaires.

This project does not involve any risks and care will be taken to protect your identity. This will be done by keeping all responses anonymous as no personal information will be collected from you.

By participating in this project, you will be helping to further knowledge on how to design e-learning systems to meet the needs of students with disabilities.

You will have the right to end your participation in the study at any time, for any reason, up until December 15, 2014. If you choose to withdraw, all the information you have provided will be destroyed.

All research data, including electronic questionnaires will be encrypted and password-protected. Any hard copies of data (including any handwritten notes or USB keys) will be kept in a locked cabinet at the University of Ottawa. Research data will only be accessible by the researcher and the research supervisor.

This project was reviewed by the University of Ottawa Research Ethics Board, which provided clearance to carry out the research. Clearance expires on (insert date here). If you have any questions regarding the ethical conduct of this study, please contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5, Tel.: (613) 562-5387, Email: ethics@uottawa.ca

If you would like to participate in this research project, or have any questions, please contact me at 613-562-5800 extension 2700 or jtanyung@uottawa.ca.

Sincerely,

Julius Tanyu Nganji

Courriel Invitation - Étudiants

Objet: Invitation à participer à un projet de recherche sur la Personnalisation de ressources d'apprentissage pour les étudiants en situation de handicap.

Cher Monsieur ou Madame,

Mon nom est Julius Tanyu Nganji et je suis un étudiant au doctorat en informatique au Département d'informatique, Faculté des sciences à l'Université de Hull, Royaume-Uni. Je travaille sur un projet de recherche sous la supervision du Dr Mike Brayshaw.

Je vous écris aujourd'hui pour vous inviter à participer à une étude intitulée «Personnalisation de ressources d'apprentissage pour les étudiants en situation de handicap ». Cette étude vise à faciliter l'accès aux matériaux d'apprentissage pour les étudiants en situation de handicap dans un environnement d'apprentissage électronique.

Seuls les étudiants ayant des handicaps suivants participeront à cette étude: La basse vision, la déficience auditive et la dyslexie. Comme le logiciel est entièrement en anglais, l'évaluation et les questionnaires seront uniquement en anglais. La sélection pour cette étude se fera sur la base du principe premier arrivé, premier servi. Le délai de participation à cette étude est le 15 décembre 2014.

Cette étude pourra durer de 45-60 minutes selon l'individu et sera effectuée dans l'une des salles d'étude à l'Université d'Ottawa. Pendant ce temps, vous allez interagir avec un logiciel d'apprentissage électronique sur un ordinateur, exécuter certaines tâches et remplir des questionnaires.

Ce projet ne comporte pas de risques et l'information que vous partagerez restera strictement confidentielle. Ce sera fait en gardant toutes les réponses anonymes, aucune information personnelle ne sera collectée auprès de vous.

En participant à ce projet, vous aiderez à mieux connaître la façon de concevoir des systèmes d'apprentissage en ligne pour répondre aux besoins des étudiants en situation de handicap.

Vous aurez le droit de mettre fin à votre participation à l'étude à tout moment, pour une raison quelconque. Si vous choisissez de retirer votre participation, toutes les informations que vous avez fournies seront détruites.

Toutes les données de recherche y compris les questionnaires électroniques seront cryptées et protégées par mot de passe. Toutes copies papier des données (y compris les notes manuscrites ou clés USB) seront conservées dans une armoire verrouillée à l'Université d'Ottawa. Les données de recherche seront uniquement accessibles par le chercheur et le directeur de recherche.

Ce projet a été examiné par le comité d'éthique en recherche à l'université d'Ottawa, qui a fourni l'autorisation de mener la recherche. L'autorisation éthique pour cette étude expire le (insérer la date ici). Si vous avez des questions concernant l'éthique de cette étude, s'il vous plaît contacter le responsable de l'éthique en recherche à l'Université d'Ottawa, Pavillon Tabaret, 550 rue

Appendix B: Email Invitation to Students

Cumberland, pièce 154, Ottawa, ON K1N 6N5, Tél .: (613) 562 -5387, Courriel: ethique@uOttawa.ca

Si vous souhaitez participer à ce projet de recherche, ou vous avez des questions, s'il vous plaît contactez-moi au 613-562-5800, poste 2700 ou jtanyung@uOttawa.ca.

Cordialement,

Julius Tanyu Nganji

Appendix C: ONTODAPS Student Evaluation Questionnaire

Questionnaires

What is your gender? Male ☐ Female ☐

Computer proficiency: Novice ☐ Intermediate ☐ Advanced ☐

Have you ever used a VLE/LMS before? Yes ☐ No ☐

Name some Learning Management Systems (LMS) or Virtual Learning Environments (VLE) you know.

Your disability type:

Hearing impairment ☐ Dyslexia ☐ Low vision ☐ Other (Please specify) -----

Age: 17-20 ☐ 21-25 ☐ >25 ☐

LMS/VLE are easy to use.

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

I find it easy to search learning materials within a LMS/VLE?

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

I found using ONTODAPS beneficial.

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

The results obtained from using ONTODAPS aided my learning experience.

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

I would use ONTODAPS again if its functionality was incorporated into another LMS/VLE.

- Strongly Disagree (1)
- Disagree (2)
- Uncertain (3)
- Agree (4)
- Strongly Agree (5)

Overall ONTODAPS was very effective.

- Strongly Disagree (1)
- Disagree (2)
- Uncertain (3)
- Agree (4)
- Strongly Agree (5)

Sometimes I found using ONTODAPS very confusing.

- Strongly Disagree (1)
- Disagree (2)
- Uncertain (3)
- Agree (4)
- Strongly Agree (5)

The materials retrieved using ONTODAPS were relevant to my learning needs?

- Strongly Disagree (1)
- Disagree (2)
- Uncertain (3)
- Agree (4)
- Strongly Agree (5)

Overall how effective did you find the ONTODAPS Environment?

- Excellent (5)
- Very good (4)
- Satisfactory (3)
- Fair (2)
- Poor (1)

Did you identify any errors within the ONTODAPS environment and if so what were they?

The Font was consistent throughout the ONTODAPS environment.

- Strongly Disagree (1)
- Disagree (2)
- Uncertain (3)
- Agree (4)
- Strongly Agree (5)

The text size was consistent throughout the ONTODAPS environment.

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

The presentation of the ONTODAPS environment was consistent throughout.

Strongly Disagree (1)

Disagree (2)

Uncertain (3)

Agree (4)

Strongly Agree (5)

How do you think the ONTODAPS environment could be improved?

What have you learnt from using the ONTODAPS environment?

How would you rate the overall effectiveness of the ONTODAPS environment between 1 (Excellent) and 5 (Poor)

Poor (5)

Fair (4)

Satisfactory (3)

Very Good (2)

Excellent (1)

For your disability type, what format of learning materials is best suited for you?

When designing an e-learning environment, what considerations should be taken to consider your needs?

What would be an ideal learning environment for you in terms of design and functionality?

What features of ONTODAPS were most useful to you?

How do you edit your profile in ONTODAPS?

How do you select learning goals in ONTODAPS?

How do you personalize learning materials in ONTODAPS?

How do you change the font size in ONTODAPS?

Appendix D: ONTODAPS Recruitment Poster

Recruitment Poster - Students

Participate in a study on personalizing learning resources for students with disabilities!

To participate, you must have one or more of:

- ✓ **Low vision**
- ✓ **Hearing impairment**
- ✓ **Dyslexia**

And:

- ✓ **Be comfortable in the English language**

This is a **45-60 minute study**. You will be asked to interact with a piece of software, carryout some tasks and answer questions about your experience.

Selection for this study will be on a **first-come, first-served** basis.

This project has been reviewed and cleared by the University of Ottawa Research Ethics Board at 613-562-5387 or ethics@uottawa.ca

Please contact the researcher, Julius Tanyu Nganji, for more details on this study at jtanyung@uOttawa.ca

Affiche de recrutement - Étudiants

**Participer à une étude sur la
personnalisation des ressources
d'apprentissage pour les étudiants
en situation de handicap!**

Pour participer, vous devez avoir l'un des
handicaps suivants:

- ✓ **Basse vision**
- ✓ **Déficiência auditive**
- ✓ **Dyslexie**

Et:

- ✓ **Être à l'aise dans la langue anglaise**

Il s'agit d'une étude de **45-60 minutes** qui sera réalisée **uniquement en anglais**. Vous serez invité à interagir avec un logiciel, exécuter certaines tâches et répondre aux questions sur votre expérience.

La sélection pour cette étude se fera sur la base du principe **premier arrivé, premier servi**.

Ce projet a été examiné et approuvé par le comité d'éthique en recherche à l'université d'Ottawa au 613-562-5387 ou ethique@uOttawa.ca

S'il vous plaît, communiquer avec le chercheur, Julius Tanyu Nganji, pour plus de détails sur cette étude: jtanyung@uOttawa.ca

Appendix E: ONTODAPS User Task Scenarios - Students

Please carry out the following tasks and where appropriate, record the accuracy, completion time, number of errors made and any problems encountered. **Please do not use your true name or email addresses or that of anyone you know and do not use any information that will identify you.**

Baseline Experiment

Task 1: From the repository of learning materials, find the materials that will help you meet the goal to **improve your knowledge on Biology**. In the table below, record the title of the materials retrieved and their formats. State if the materials are relevant to the goal and if the format is suitable for you. Use Y for Yes and N for No.

[illegible]

Appendix E: ONTODAPS User Task Scenarios

Task 2: From the repository of learning materials, find the materials that will help you meet the goal to **learn the software Read & Write**. In the table below, record the title of the materials retrieved and their formats. State if the materials are relevant to the goal and if the format is suitable for you. Use Y for Yes and N for No.

Title of learning material	Format (video, audio, text)	Relevant? (Y/N)

Task 3: From the repository of learning materials, find the materials that will help you meet the goal to **learn the software Inspiration**. In the table below, record the title of the materials retrieved and their formats. State if the materials are relevant to the goal and if the format is suitable for you. Use Y for Yes and N for No.

Title of learning material	Format (video, audio, text)	Relevant? (Y/N)

Intervention Experiment (with software)

No	Tasks	Accuracy of task completion (effectiveness)	Task completion time (efficiency)	Number of errors made	Problems encountered
1	Registering as a new user Register in the system as a new user with a different username and password and login to the system. <u>Do not use your true name or email or any information that will identify you.</u>	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
2	Selecting learning goals Select the following learning goals from the list of goals and assign those goals to yourself: (a) Learn Biology (b) Learn Read & Write (c) Learn Inspiration	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
3	Personalising courses Select the courses that meet the above learning goals and personalise the courses	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
4	Accessing learning resources For the courses you personalised, open one or more formats of the learning resources to access its content	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			

Appendix E: ONTODAPS User Task Scenarios

For the learning materials personalised to you using the software, please record the following information:

No	Learning goal	Total Number of materials retrieved	Number of relevant materials	Number of irrelevant materials	Format(s) of materials retrieved (Video, Audio, Text)	Are the formats retrieved suitable for your disability type? (Yes or No)
1	Learn Biology					
2	Learn Read & Write					
3	Learn Inspiration					

Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

Dear Evaluator,

Thank you for accepting to help evaluate the Ontology-Driven Disability-Aware Personalised E-Learning System (ONTODAPS), an ontology-based system that helps personalise e-learning resources for disabled students.



Heuristic evaluation is a usability inspection method that will help to check that the ONTODAPS visual interface will be usable to the intended disabled users and this method uses a small set of evaluators who will judge the user interface for compliance with some usability design principles (heuristics). It is usually recommended that 3-5 evaluators carry out heuristic evaluation as this number of evaluators can find about 75% of errors that may exist in the system. During this process, you will be required to judge the interface and record any findings in the attached questionnaire. As ONTODAPS is used in an educational setting, Nielsen's (1994) ten *interface design heuristics* have been combined with some of Quinn's (1996) *educational design heuristics* and some of Squires and Preece's (1999) *learning with software heuristics* to ensure that most of the errors in the system are detected.

Please take some time to familiarise yourself with ONTODAPS, going through it twice before evaluating the interface. Please go through the heuristics given and see how they relate to ONTODAPS. If you find any usability or learning problem, please record the severity of the problem against the scale provided. Also, kindly rate ONTODAPS on a scale of 10, based on the individual heuristics by checking the appropriate score.



With many thanks,

Julius T. Nganji

Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

Heuristic	Quality Indicator	Severity scale of identified problems (if any)	
<p><i>ONTODAPS ensures visibility of systems status (Nielsen, 1994)</i></p> <div style="text-align: center;">  <p>1</p> </div>	<p>ONTODAPS keeps the user informed about what is going on, through appropriate and timely feedback. The user can move on to other tasks.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS provides a match between the system and the real world (Nielsen, 1994)</i></p> <div style="text-align: center;">  <p>2</p> </div>	<p>ONTODAPS speaks the user's language with familiar words, phrases and concepts and information appears in a natural and logical order. The content is in an appropriate format for various disabilities.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>

Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

<p><i>ONTODAPS is flexible enough to provide the user enough control and freedom (Nielsen, 1994)</i></p> <div style="text-align: center;">  <p>3</p> </div>	<p>ONTODAPS provides a means of exiting the software</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS is consistent and follows common operating system standards (Nielsen, 1994)</i></p> <div style="text-align: center;">  <p>4</p> </div>	<p>ONTODAPS is consistent in the words, actions and situations. The menus follow platform standards.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>

Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

<p><i>ONTODAPS prevents errors (Nielsen, 1994)</i></p> <div data-bbox="297 475 394 568" data-label="Image"> </div>	<p>ONTODAPS is designed to prevent errors from occurring during use. It provides guidance (e.g. a Help menu) to reduce the risk of errors</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS supports recognition rather than recall (Nielsen, 1994)</i></p> <div data-bbox="297 1054 394 1147" data-label="Image"> </div>	<p>In ONTODAPS, the objects, actions and options are visible. Instructions or guidance on how to use the system (e.g. Help Menu or introductory video, audio or text) is visible and retrievable whenever appropriate.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>



Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

<p><i>ONTODAPS supports flexibility and efficiency of use (Nielsen, 1994)</i></p> <div data-bbox="297 544 394 635" data-label="Image"> </div>	<p>ONTODAPS allows flexibility for inexperienced and experienced users. Experienced users can use shortcuts (e.g. Ctrl+C, Ctrl+X, Ctrl+V for copy, cut, paste respectively or Alt+F4 to exit, etc.), can change the font type and size to suit their needs, etc.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS uses aesthetic and minimalist design (Nielsen, 1994)</i></p> <div data-bbox="286 1134 383 1225" data-label="Image"> </div>	<p>ONTODAPS has an aesthetically pleasing design and does not contain information which is irrelevant or rarely used.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>



Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

<p><i>ONTODAPS helps users recognise, diagnose and recover from errors (Nielsen, 1994)</i></p> <div data-bbox="297 544 394 635" data-label="Image"> </div>	<p>ONTODAPS error messages are expressed in plain language, indicating the problem and suggesting a solution</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS provides help and documentation (Nielsen, 1994)</i></p> <div data-bbox="336 935 432 1026" data-label="Image"> </div>	<p>ONTODAPS has a help menu which shows users how to accomplish basic tasks. There is a documentation in various formats (video, audio, text) which is easily accessible and is presented in a suitable format to meet the special needs of the disabled user.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>



Appendix F: ONTODAPS Heuristic Evaluation Questionnaire

<p><i>ONTODAPS has clear goals and objectives</i> (Quinn, 1996)</p> <div data-bbox="297 534 394 627" style="text-align: center;">  <p>11</p> </div>	<p>ONTODAPS makes it clear to the learners what it is to be accomplished and what will be gained from its use</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS context is meaningful to domain and learner</i> (Quinn, 1996)</p> <div data-bbox="284 917 380 1010" style="text-align: center;">  <p>12</p> </div>	<p>The ontology-based personalisation offered by ONTODAPS is situated in practice and will interest and engage the learner</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>

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<p><i>ONTODAPS content clearly and multiply represented and multiply navigable</i> (Quinn, 1996)</p> <div data-bbox="297 512 394 604" style="text-align: center;">  <p>13</p> </div>	<p>ONTODAPS message is unambiguous. It supports learner preferences for different access pathways. The learner is able to find relevant information while engaged in an activity</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS provides navigational fidelity</i> (Squires and Preece, 1999)</p> <div data-bbox="297 1042 394 1134" style="text-align: center;">  <p>14</p> </div>	<p>ONTODAPS interface design does not mislead the learner to focus on the interface rather than learning issues. The interface supports learning.</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>

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<p><i>ONTODAPS provides appropriate levels of learner control</i> (Squires and Preece, 1999)</p> <div data-bbox="297 550 394 641" style="text-align: center;">  <p>15</p> </div>	<p>ONTODAPS allows learners to self-direct their learning through personalising learning resources and allowing them to choose which resources to access. This gives the learner a sense of ownership and control</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>
<p><i>ONTODAPS supports personally significant approaches to learning</i> (Squires and Preece, 1999)</p> <div data-bbox="264 986 360 1077" style="text-align: center;">  <p>16</p> </div>	<p>ONTODAPS considers different learning styles and presents materials in alternative formats suitable for various disabilities</p>	<p>Score/10</p> <p>0 <input type="checkbox"/></p> <p>1 <input type="checkbox"/></p> <p>2 <input type="checkbox"/></p> <p>3 <input type="checkbox"/></p> <p>4 <input type="checkbox"/></p> <p>5 <input type="checkbox"/></p> <p>6 <input type="checkbox"/></p> <p>7 <input type="checkbox"/></p> <p>8 <input type="checkbox"/></p> <p>9 <input type="checkbox"/></p> <p>10 <input type="checkbox"/></p>	<p>0- I don't agree that this is a usability problem at all</p> <p>1- Cosmetic problem only; need not be fixed unless extra time is available</p> <p>2- Minor usability problem; fixing this should be given low priority</p> <p>3- Major usability problem; important to fix; so should be given a high priority</p> <p>4- Usability catastrophe; imperative to fix before this product is released</p>

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Please use the space below for any comments/suggestions you have

Appendix G: ONTODAPS Heuristic Evaluation Tasks

Please carry out the following tasks, recording the accuracy, completion time, number of errors made and any problems encountered. **Please do not use your true name or email addresses or that of anyone you know and do not use any information that will identify you.**

No	Tasks	Accuracy of task completion (effectiveness)	Task completion time (efficiency)	Number of errors made	Problems encountered
1	Registering as a new user Register into the system as an admin then register a new student into the system and assign a learning goal to them. Selecting disability type as Visual Impairment and severity as moderate.	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
2	Adding courses Add a new course and upload learning resources for that course in three formats: text, audio and video.	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
3	Assigning learning goals to courses Create a new learning goal for the course you just created, assign that learning goal to moderate visual impairment and to that course.	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			

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No	Tasks	Accuracy of task completion (effectiveness)	Task completion time (efficiency)	Number of errors made	Problems encountered
4	Accessing learning resources For the course you just created, click to view the video, audio and text.	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			
5	Editing user information Change the email address of the user you registered, and then change your own email.	Correct <input type="checkbox"/> Partial <input type="checkbox"/> Failure <input type="checkbox"/>			