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A Reference Computational Model to Manage the Semantics of Learning Environments using SWRL Enabled OWL Ontologies

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A Reference Computational Model to Manage the Semantics of Learning Environments using SWRL Enabled OWL Ontologies

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Declaration

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Publications:

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3) Almami, E., Patel, F., Koay, N., Juric, R., Everiss, C., (2012). Towards identifying teaching practices using assistive technologies through ontological reasoning: A Case Study of Pupils with Autism. In Proceedings of the: SDPS 2012, Conference. 10-14 June 2012, Berlin, Germany.

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March 2017

Dedication

This thesis work is dedicated especially to my husband Mr Mohammadhaitham Dabbour, who has been a constant source of support and encouragement during the challenges of graduate school and life and also for his remarkable patience. Hism, I am truly thankful for having you in my life.

The greatest pleasure for me is writing dedications and acknowledgements for this thesis to my family, especially to my Mother Mrs. Samirah Abdulkader, for your love, constant support and understanding.

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Abstract

This thesis proposes a reference model and its computational core to support the creation of software applications within educational environments, which address Differences In Learning (DiffInL) and are applicable to both learners and instructors. This work differs from others in that the strength of this model resides on the re-usable character of the reasoning mechanism enabled by the computational environment. The starting point is the definition of agreed learning goals that the learner needs to achieve. In turn, the reference model generates personalised, best-practice teaching and learning materials, suitable for achieving the individual's learning goals.

This reference model consists of MODEL and MANAGEMENT components. The MODEL components store the domain needed to create learners and instructional models, which are required for the creation of Learning Spaces (LeS). The MANAGEMENT component also manages the semantics stored in various model components in order to carry out the configuration of an LeS.

The architecture of software applications generated from the reference model is illustrated and contains: Netbeans IDE 8.0.2, JavaServer Faces framework and OWL-API library. We tested this to generate teaching practices for Learning Difficulties (LDif) student.

In order to prove the feasibility of creating a software application from the reference model, an example of a particular scenario in a specific educational setting for LDif Students has been shown. This proposed model has successfully proved its ability to address the needs of LDif Students through a corresponding novel and re-usable reasoning mechanism implemented in Web Ontology Language (OWL) and Semantic Web Rule Language (SWRL) computational environments. The reference model has shown its ability to integrate with different disciplines such as psychology, sociology and human-computer interactions.

The main contribution to research is the creation of a novel reference computational model which addresses the needs of people with DiffInL. The strength of this model resides on the re-usable character of the reasoning mechanism enabled by the computational environment. The whole framework allows a unified implementation which takes into account classes, constraints, matching, and inference mechanisms for the complete configuration of an LeS.

The suggested approach also differs from previous work in that it is personalised, and the applied reasoning rules are dynamic. Therefore this model can be constantly “tuned” according to the questions we may ask in such environments.

Overall, the proposed reference model in this research offers a promising and feasible solution that can support current educational systems and benefit both learners and instructors. It also demonstrates the applicability of the latest technologies and would allow for future technologies to be incorporated, in order to enhance the model.

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Listings

List of Abbreviations

ADD .... **A**ttention **D**eficit **D**isorders

ADHD .... **A**ttention **D**eficit **H**yperactivity **D**isorder

ADLs .... **A**dult **L**earning **E**nvironments

ADOOLES .... **A**dult **D**isabilities **O**ntology for **O**nline **LE**arning and **S**ervices

AI .... **A**rtificial **I**ntelligence

AIED .... **A**rtificial **I**ntelligence in **ED**ucation

AIM-lab .... **A**utomated **I**nternet **M**easurement **Lab**

API .... **A**pplication **P**rogram **I**nterface

ASD .... **A**utism **S**pectrum **D**isorder

AWBES .... **A**daptive **W**eb-**B**ased **E**ducational **S**ystems

CBSD .... **C**omponent **B**ased **S**oftware **D**evelopment Committee on Disabilities

CONON .... **CON**text **ON**tology

COSE .... **C**reation **O**f **S**tudy **E**nvironments

CQ .... **C**ompetency **Q**uestions

CSCL .... **C**omputer **S**upported **C**ollaborative **L**earning

DB .... **D**ata**B**ases

DCD .... **D**evelopmental **C**oordination **D**isorder

DiffInL .... **Dif**ferences **In** **L**earning

DIL .... **D**river **I**nterface **L**ayer

DL .... **D**escription **L**ogic

EUD .... **E**nd-**U**ser **D**evelopment

GUI .... **G**raphic **U**ser **I**nterface

IDEA .... **I**ndividual with **D**isabilities **E**ducation **A**ct

IQ .... **I**ntelligence **Q**uotient

IR .... **I**nformation **R**etrieval System

IT .... **I**nformation **T**echnology

ITPA .... **I**llinois **T**est of **P**sycholinguistic **A**bilities

ITS .... **I**ntelligent **T**utoring **S**ystem

JMF .... **J**ava **M**edia **F**ramework

LDif .... **L**earning **D**ifficulties

LD .... **L**earning **D**isabilities

LE .... **L**earning **E**nvironments

LeS .... **Le**arning **S**paces

ManSemLeS ... **Man**aging **Sem**antics of **Le**arning **S**paces

NACHC .... **N**ational Advisory Committee on Handicapped Children

NJCLD .... **N**ational Joint Committee on Learning Disabilities

KB .... **k**nowledge **b**ase

OWL .... **W**eb **O**ntology **L**anguage

PLC .... **P**rogrammable **L**ogic **C**ontrollers

QL .... **Q**uery **L**anguage

RDF .... **R**esource **D**escription **F**ramework

RDFS .... **R**esource **D**escription **F**ramework **S**chema

RTE .... **R**un-**T**ime **E**nvironment

SCORM .... **S**harable **C**ontent **O**bject **R**eference **M**odel

SE .... **S**oftware **E**ngineering

SEN .... **S**pecial **E**ducational **N**eed

SLD .... **L**earning **D**isabilities

SOUPA .... **S**tandard **O**ntology for **U**biquitous and **P**ervasive **A**pplications

SpLDs .... **S**pecific **L**earning **D**ifficulties

SQL .... **S**tructured **Q**uery **L**anguage

SW .... **S**emantic **W**eb

SWRL .... **S**emantic **W**eb **R**ule **L**anguage

SWT .... **S**emantic **W**eb **T**echnology

TM4L .... **T**opic **M**aps **for** e-**L**earning

URI .... **U**niform **R**esource **I**dentifier

URL .... **U**niform **R**esource **L**ocator

USOE . . . . **US** **O**ffice of **E**ducation

VIC . . . . **VI**deo **C**onferencing tool

W3C . . . . **W**orld **W**ide **W**eb **C**onsortium

Web . . . . **W**orld **W**ide **W**eb

WWW . . . . **W**orld **W**ide **W**eb

XML . . . . **X**tensible **M**arkup **L**anguage

Chapter 1

Introduction

Members of any society are diverse. They differ in many ways, e.g. ethnicity, gender, religion, race, age, physical appearance and disability status. However, societies cannot prosper unless each individual is given an equal opportunity to reach their full potential and to thrive. Within the UK educational system there is one particularly vulnerable group of students who have been consistently forgotten – those with Learning Difficulties/Disabilities (LDif/LD). The government introduced an initiative called "Every Child Matters" in 2003, yet in terms of the needs of children with LDs it seems that some children matter more than others. Mahatma Gandhi believed that "A society is judged by how it treats its most vulnerable members" (Gregg & Gandhi, 1960) . If this is true, then the disability divide, which still exists within the learning community, needs to be recognised (Nganji, Brayshaw & Tompsett, 2011). If the British educational system is to to be one which embraces equality and diversity, then the aim should be to constantly review, analyse and improve practice to ensure that the most vulnerable students are enabled and empowered, to avoid a system based on social Darwinism, or the survival of the fittest.

At present the school system is something of a lottery. If you are part of the privileged 90% who do not have LD, then your chances of academic success are immediately greater. If, on the other hand, you have LD, then you are less likely to be able to access education, to enjoy the learning experience and to achieve your potential. One example of this is referenced by Hollier (2007) who states that LD learners are excluded from technology allowing them to access online web information, particularly in Higher Education, where there is currently a lack of sufficient reasonable adjustments (Hollier, 2007). LD students are often described in terms of deficit, as though they do not reach the benchmark, or in other words they are failures. The semantics of disability could be perceived as discriminatory, and the prefix "dis" is often used, which suggests that LD individuals are missing, or without some particular quality or attribute. The author wishes to encourage a shift in thinking, and challenge this negative language, and will therefore focus more on “ability” than “disability”. The social model of disability is fundamental to the ethos of this thesis, meaning that the LD student may well have learning “differences”, but these only become “difficulties” when they interface with a society which disables them by putting obstacles in their path.

The aim of this study is to play a small part in redressing the balance and shifting the fulcrum of the disability divide to serve the needs of LD students, opening up online web learning possibilities for them which will suit their unique learning styles and enhance their educational and life chances. Accommodating the learning needs of LD people by including them in main stream education is therefore considered by a number of educationalists as one of the most important objectives of learning provisions (Reid & Valle, 2004) (Bouck, 2007) (Greville, 2009) (Belcher, 2015) (Baglieri et al., 2011). Students with LDs are not equal in their needs as they experience diverse challenges which are commonly hidden, and may vary in severity and areas affected (Alberta Learning, 2000-2003) (Tungland, 2002). Historically, experts in the field, have tried to classify LD students, in order to manage the learning environment and address the different needs of participants (Leonardi* et al., 2005). (Noonan et al., 2009) and (Leyin, 2010) offer a detailed explanation of types of LDs, and give classifications of these.

Modern, Virtual Learning Environments (VLEs) are capable of accommodating the variety of needs of students and generating personalised learning plans, according to their needs and abilities. They are at the same time a very powerful mechanism of simulating a real world classroom, and enhancing students’ experiences through a plethora of technologies and devices (Falk & Dierking, 2002) (Peters & Rosson, 2008). In this research the special needs of students with disabilities is focused on, in terms of creating a pervasive software environment (O’Sullivan, Lewis & Wade, 2004) (Koay, Syal & Juric, 2010) (Reddy, 2006) where VLEs can reside, and students with disabilities can choose to participate, and where the leaning outcomes and expectations of instructors and educators can be satisfied.

1.1 Motivation Behind the Research

A number of researchers have addressed the problems that LD people face when trying to learn. However, the majority of studies conducted have focused predominantly on learning and teaching practices (Brown, Collins & Duguid, 1989) (Miller, Lombard & Hazelkorn, 2000) (Odom et al., 2003) (Babu & Peter, 2011) (Swanson et al., 2012) (Lee & Picanco, 2013), and have made a serious omission by not fully considering the vital role technological advances offer (Falk & Dierking, 2002) (Kumar et al., 2003) (Kumar, 2003) (Munoz et al.,

2006) (Ma & Kumar, 2007) (Stronge et al., 2007) (Al-Ajlan & Zedan, 2008) (Kumar et al., 2009).

As an academic involved in designing effective and interactive online technologies, and also as the mother of a child with autism, I feel passionately about improving accessiblity to learning for people with LDs. The development of a reference computational model is a part of my journey as a professional and a parent, in terms of construcing a meaningful method for disabled learners to broaden their horizons. The programme will open up a wealth of rich, exciting and educational materials to motivate them, accommodate their individual learning needs and goals, thus allowing them to realise their full potential.

1.2 The Research Problem

Current solutions that address the needs of the LD students in education are often fragmented to either the type of students' disability or their learning process. They are also heavily dependent on;

- software tools (Kao et al., 2010) (Chen & Kagawa, 2010) (Kao, Wang & Huang, 2010) (Mohammad, 2010) (Gandomi & Knight, 2010) (Hammami, 2010)
- various types of virtual environments (Cheng et al., 2005) (Gerrard, 2007) (Harrison, Stockton & Pearson, 2008) and
- special settings in classrooms which deal solely with student's needs (Flores, 2003).

To complicate the situation more, there are so many different definitions of disabilities and it is almost impossible to reach a quick consensus on what they really are and how they can be classified in order to understand their impact on learning processes. Classifications found in (Fried et al., 2000) (Rahi & Dezateux, 1998) (Leyin, 2010) put forward Cognitive/ Learning Disability as " a condition which limits brain functions of an individual". According to (Goldsmiths University 2011), disability hinders mental growth and disabled person usually faces difficulties in thinking, problem solving, expressing themselves, reading, writing and speaking.

Consequently, it may be found that Learning Disabilities (LD) is seen as a type of general disabilities (Hale et al., 2004) (Wu, Huang & Meng, 2007) (Muangnak, Pukdee & Hengsanunkun, 2010) and (Wu et al., 2010). There is very little evidence or work done which strictly distinguish between the two. Furthermore, modern literature on LD claims that most people with LD usually have only a mild disability which affects their ability to carry out mental tasks, because they suffer from abnormal physiological or biological processes in their bodies and have unbalanced chemistry or structure of their brains(Yesilada, Brajnik & Harper, 2011). Very often persons with such “minor” LD might be able to function adequately despite their disability, to the point where it is never diagnosed or noticed (Disabled World, 2015). The approach this research follows and documented in the thesis is to propose a generic software solution rather than a specific tool applicable for a particular subset of LD (Lama & Sánchez, 2009).

In this approach the proposed computational model should accommodate each and every type of LD and it should allow association between individual’s LD and their goals they want to achieve.

1.3 The Research Proposal Summary

The purpose of this research is

1) To investigate the characteristics, functionalities and contents of learning Environments (LE) which can lead towards an ad-hoc configuration of their instances, i.e. learning Spaces (LeS).

2) To identify some of the key elements of the LeS that can form a computational model as a proof of concept, that is highly personalised to learners’ needs.

The issue of personalisation of such spaces for LD students must take into account various aspects such as:

(a) various impairments; diverse range of impairments that exist among learners

(b) personal preferences; a tailored learning space and not a generic plan which offers them the range and choice of options that suit them

(c) learning needs; customised and directed support for individuals with diverse range of needs

(d) technology affinity; compatibility of any solution with assistive technologies to facilitate (a) – (c) above.

Without a comprehensive picture of learning aspects listed in (a)-(d) it would be difficult to define a conceptual model of LE which can be properly configured into a particular set of LeS. The semantics stored in such environments (LE and LeS) is extremely rich and difficult to manage, in terms of securing a correct configuration of LeS. There is a need to bring forward new ideas for defining main artefacts of configured LeS in terms of learning activities and resources which underpin them, which in turn personalise them to the actual need of anyone involved. New ideas should come from:

(i) Creating new computational models which can automate the configuration of LeS and therefore deal with their main artefacts. This is important because of the reliance on technologies in modern classroom, which is changing the way that activities are automated and deal with main artefacts of a LeS.

(ii) Defining an appropriate reference model, which accommodates its computational model from (i) above and secures the implementation of a LeS.

1.4 Research Objectives

There are three important research objectives in this work:

(OB1) To put forward the requirement (c) from above as the most important objective and manage the semantics of LE and the configuration of LeS by identifying the needs of learners who exhibit a range of differences in learning, DiffInL.

(OB2) To address (a) and (b) from above to make sure all different types of disability/difficulty learners have are addressed, and accordingly practices suitable for their impairments can be utilised in light of (d) and (OB1) above.

(OB3) To propose a reference and implement a computational model which takes into account (i) and (ii) from above and secures a successful ad-hoc configuration of a LeS for individuals who have DiffInL.

1.5 Expected Contribution of the Research

This interdisciplinary research spans software engineering, education, cognitive science and pervasive technologies. The contribution will be threefold:

1. There will be a new computational model which will address the needs of people with DiffInL and secure computational spaces which configure a LeS, which in turn will satisfy the research objectives and objective (3) in particular. This will take into account creating and implementing a new computational model, that allows for the personal preferences of a learner to suit a diverse range of impairments. It will also secure successful ad-hoc configuration of a LeS for DifflnL students.

2. There will be a novel and re-usable reasoning mechanism in OWL and SWRL enabled computational environments. The reason it is innovative is that it can be used for utilising a specific computational model described in 1) above. This means that a consensus will be able to be delivered on how to exploit the semantics from the computational environments in terms of OWL classes, constraints and their mapping for the purpose of configuring any LeS.

3. There will be an opportunity to re-use results from 1) and 2) above in terms of allowing better integration of disciplines such as psychology, sociology, human-computer interactions, digital design and multimedia when implementing the computational model.

It is important to note that, apart from highlighting research issues from the objectives in section 1.4, awareness will also be highlighted about the power of technologies when creating personalised spaces suitable for learning in current LE, where LDs in particular can be addressed.

1.6 Research Approach

The approach this research follows is a thorough analysis of the learning environment to organise an ontological structure representing key concepts of this environment, particularly taking into account LD learners.This will be followed by focusing on selected elements of the ontology to propose a computational model based on OWL ontology and reasoning upon it. A proof of concept implementation of the proposed model upon which a Java application runs will validate the model.

The reasoning mechanism using a reasoning engine will reason upon each individual user's particular LD and their goals to suggest specific practices they will need to exercise to address their needs.

Therefore, this thesis proposes a generic software solution rather than a specific tool applicable for a particular subset of LDs. In this approach the proposed computational model should accommodate each and every type of LD and it should allow association between an individual's LD and the goals they want to achieve.

1.7 Research Method

a) The research starts with establishing a definition of learning disability and difficulties, and common types of LDs are briefly explored;

b) Supporting technologies for LDs that are currently available are reviewed;

c) The semantics of learning environments accommodating all pertinent concepts of a learning space for LD learners is modelled.

d) Through continuous refinement a reference computational model based on key concepts identified in c) above will be created;

e) The model designed in d) above will be implemented as a proof of concept to show the applicability of the proposed model to provide a personalised service to a LD student seeking appropriate practice suitable for her/his needs at a particular moment.

1.8 Thesis Structure

The thesis is structured as follows:

In **Chapter 2** some background information regarding the research issues is provided. Learning difficulties are explained in three subsections in section 2.1 from the perspective of disabilities, supporting technologies and supporting VLEs. Section 2.2 and 2.3 cover the semantics of learning difficulties and delivery of personalised education to students with learning difficulties respectively. In section 2.4 some of the technologies from the Semantic Web Stack pertinent to the research are explained in detail followed by section 2.5 which extends the definition in the previous section to SWRL enabled OWL ontologies. The chapter concludes in section 2.6 with an overview of how different concepts and technology explained in this chapter are applied in the research.

In **Chapter 3** the research problem is specified followed by a full account of related works.

In **Chapter 4** the research proposal is explained. The outline of the shortcomings of existing solutions is covered in section 4.1 and followed by proposed solution in section 4.2. Next section of this chapter explains in full detail the proposed reference model.

In **Chapter 5** the implementation is elaborated. The motivation scenario and the competency question is covered in section 5.1. Section 5.2 walks the reader through the application of ontological model including the creation of the learning space.

In **Chapter 6**, which includes 6.1 – 6.7, the thesis is summarised, with an evaluation and reflection of the objectives, a summary of the contributions of current research and a critique. This is followed by a final conclusion and suggestions about future work that the author of this thesis may undertake.

Chapter 2

Literature Review

This chapter provides some historical background of the definitions suggested by scholars for the term ‘learning disability’. Through this study which goes back to 1960s another interchangeably used term, ‘learning difficulty’ is also reviewed. After this clarification, the chapter briefly explains seven common types of disabilities, such as dyslexia, or autism along with their demographics. This follows by some description of technologies used to help out individuals who have learning difficulties. The chapter elaborates then on Semantic Web technologies to represent the semantics of the environment and introduces technologies that are involved in this thesis to support individuals with learning difficulties

2.1 Learning Disability Definitions

The definition of learning disabilities (LDs) is controversial due to the lack of specification and in addressing who exactly are the disable people. Traditionally, the term LD is identical to the concept of unpredicted underachievement and this include the students who are not able to listen, read, write, speak or develop the mathematical skills, albeit the viability of learning opportunities for them (Lyon et al., 2001).

In early defending, the LDs term has been associated with the inherent neurological factors, which is indicated to the requirement of special instructors for students with LD to achieve the predicted levels by using some aptitude index as IQ test (Kavale and Forness, 1995).

The history of LDs can be traced back to the early 1960’s, when Kirk first defined them as ‘unpredicted underachievement’ (Kirk, 1962). This definition has been accepted by the formal education community (Doris, 1993) Within his definition, Kirk references a variety of disorders that usually affect the learning, language, and communication skills (Kirk, 1962).

He defined LD as a delaying syndrome, or a delay in the development of one or more of the learning procedures, such as speaking, writing, reading, spelling, language or intellectual disabilities as a result of a possible brain dysfunction, behavioural or emotional disruptions, rather than as a consequence of mental retardation (Kirk, 1962). The learning disabilities term has been widely accepted by the educational sector because it is a more positive term, and addressed the potential concerns raised by professionals and parents in terms of previous negative language which stigmatised the learner, rather than attempting to understand and support their different learning needs (Zigmond, 1993). The following researchers have used the five essential components in Kirk's definition:

1. Underachievement, either in reading, arithmetic and writing, of achievement-related behaviour difficulties, e.g. language or speaking skills
2. Intra-individual differences. This means that the underachievement, or the achievement-related behaviour only affects one, or a few areas. In other areas, however, the learner will achieve either average, or possibly above-average results.
3. Psychological processing problems.
4. Cerebral dysfunction.
5. The exclusion of disabling conditions such as mental retardation, as well as the impact of the learner's environment as causal factors.

Whilst taking into account all of the five components Kirk mention above, each researcher then focused on one specific component (Hallahan and Mercer, 2001, Hallahan et al., 2005, Hallahan et al., 2010). For example, Bateman drew from all of the components in Kirk's LD definition, but he particularly highlighted 1), underachievement, as a fundamental factor and introduced the discrepancy model to identify the LD students (Bateman, 1965) (Hallahan et al., 2005). Similarly, Monore introduced the idea of the discrepancy concept and she also developed a diagnostic test to identify students with reading disabilities.

Kirk refined and established an assessment approach to diagnose a specific LD in children known as the Illinois Test of Psycholinguistic Abilities (ITPA). Although, the ITPA model failed to be an effective diagnostic method, it built up the concept that LD students have intra-individual differences and highlighted the idea of pinpointing perspective teaching (Hallahan et al., 2010, Hallahan et al., 2005, Hallahan and Mercer, 2001).

Subsequent to Kirk definition of LD, The legislative definition which emerged in the same period, firstly from the federal government and later from the US Office of Education (USOE), presented by the National Advisory Committee on Handicapped Children (NACHC), provided a variety of strategies for both educational models and technical assistance (Kavale and Forness, 2000).

During the 1970s, this became the most popular definition amongst different educational departments, especially when the idea of an ability-achievement discrepancy was incorporated (Hallahan et al., 2010, Hallahan et al., 2005, Hallahan and Mercer, 2001). Based on this idea, a variety of diagnostic and assessment tests were developed. Consequently, the researchers paid attention to developing new educational methods to overcome the academic problems associated with visual and visual-motor LD students.

Furthermore, the Individual with Disabilities Education Act (IDEA) is a definition that includes eligibility criteria about the LD.

The most important aspect in the definition is the statement of the term "specific learning disability", and the classification of disorders that include brain injury, dyslexia or development aphasia and exclude learning problems which arise as a result of hearing/visual disabilities or motor disabilities, stemming from environmental or cultural factors (Dombrowski, 2015). In addition, the IDEA also referenced the discrepancy approach (Dombrowski, 2015).

In the 1980s, a new definition emerged from the National Joint Committee on Learning Disabilities (NJCLD), based on the efforts of eleven major organizations that conduct research into LD academic achievement. This new definition was adopted by all of their members (Kavale and Forness, 1995) (Dombrowski, 2015).

The definition was also subjected to further modification several times, as the result of a growing number of LD studies and emerging knowledge and the fact that it was too broad and led to an over-diagnosis of students with LDs, rather than accurately assessing only those students with LDs. Furthermore, the latest modified form of NJCLD moved beyond the original IDEA term and criteria, as it also included, heterogeneity of LD, and considered the possibility that LD might arise as result of cerebral neuro system dysfunction. It also included underachievement and its association with psychological disorders (Kavale & Forness, 1995) (McCardle, Scarborough & Catts, 2001) (McCardle, Scarborough & Catts, 2001) (NASP, 2011)).

Furthermore, it also stated that the degree of LD of individuals varies during the life span, as a result of different learning demands (NJCLD, 1985,2001a) (NJCLD, 1990/2001b) (NJCLD, 2007). Although both of these definitions have fully registered the different viewpoints of organizations interested in LD, they have not brought closure to the issue of the definition, which remains a complex debate (Kavale & Forness, 2000).

However, it is necessary for schools to agree on one particular definition to inform their pedagogy, and the most commonly accepted definition, based on the term Specific Learning Disability (SLD) from IDEA is as follows:

"A disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. Such term includes such conditions as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such term does not include a learning problem that is primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage"* (Cortiella & Horowitz, 2014).

Definitions vary in different countries, and a lot of research on specific learning disabilities originates in America.

A recent definition for SLD was published by the American Psychiatric Association, and it was taken from the Diagnostic and Statistical Manual of Mental Disorders (DSM) (Goldsmiths University, 2011). The definition is called DSM-V and it contains a full description of LD symptoms and diagnostic criteria for a wide range of disorders.

Although, this definition was initially used by consultants of mental disorders, to guide them in the diagnosis process, there is an overlap into education and therapeutic practice. This means that educational professionals and therapists who are interested in LD can apply this definition in their research and studies (Cortiella & Horowitz, 2014). The (DSM-V) definition is as follows:

"The diagnosis requires persistent difficulties in reading, writing, arithmetic, or mathematical reasoning skills during formal years of schooling. Symptoms may include inaccurate or slow and effortful reading, poor written expression that lacks clarity, difficulties remembering number facts, or inaccurate mathematical reasoning. Current academic skills must be well below the average range of scores in culturally and linguistically appropriate tests of reading, writing, or mathematics. The individual's difficulties must not be better explained by developmental, neurological, sensory (vision or hearing), or motor disorders and must significantly interfere with academic achievement, occupational performance, or activities of daily living. Specific learning disorder is diagnosed through a clinical review of the individual's developmental, medical, educational, and family history, reports of test scores and teacher observations, and response to academic interventions" (Cortiella & Horowitz, 2014).

The following subsection will look further into the confusion which still exists about LDs. More interchangeably used terms that exist in the literature are discussed in this section.

2.1.1 Learning Disability (LD) Versus Learning Difficulty (LDif)

It is interesting to learn that the academic communities still do not have a widely accepted definition of LD (Fletcher et al., 2007) (Morfidi, Papachristos & Mikropoulos, 2010). It very often varies from country to country and government policies which regulate educational systems (Hantsweb, 2011) (Dyson, 2004).

In spite of having the term LD coined in 1963 (Kirk, 1963), experts in this field have not yet completely reached an agreement on its definition and exact meaning.

Even though a robust definition of LD is still evolving, there seems to be a consensus that the term refers to delayed development, retardation or disorder in the processes of language, speech, reading, writing, and arithmetic (Kavale & Spaulding, 2008) (Shapiro, 2011) (Ismail, Omar & Zin, 2009).

These authors describe LD as a broad category of developmental disorders with a deficit in learning in one or more domain, which can include reading, mathematics, and writing. (Abdollah, Ahmad & Akhir, 2010a) define that children in special education for LD are those who have been confirmed by medical doctors as having problem or difficulties that hold down their learning processes, including cognitive, language, speaking, reading, arithmetic, development, social and behaviour skills.

The modern LE in Western societies, which highly regulates learning and teaching practices, has lately moved towards different terminology and use either word 'difficulties' instead of disability, which may appear in the learning process (Atkinson & Walmsley, 1999) (Daniels & Porter, 2007) (Nganji & Nggada, 2011).

Whichever terminology is chosen, it would be desirable to create a common term for LDif which should be either taken from the existing research or generated for the purpose of this one. When looking at the literature, many different definitions of LDs and LDif can be found, which shows how difficult is to have a clear and uniform definition of obstacles in the learning process dictated by the existence of LDs or LDifs.

It is not only that the impact of disabilities on the learning process is not clear, it is also that LDif reflects upon cultural, educational and individual practices and the needs of people who cannot follow a prescribed educational program.

The distinction between LD and LDif continues to be a subject of debates although these two terms are often interchangeable. An interesting view has been found in (Holland, 2011), who lists a difference between LDs and LDif as follows:

LD – is a general term that refers to individuals who find it harder to learn, understand and communicate.

LDif – is often used in educational settings and refers to individuals who have specific problems with learning as a result of either medical, emotional or language problems.

However, the UK Government uses LDif throughout all their documents (Bristol CLDT's, 2004), it is also the term preferred by the Self-Advocacy Movement People First (Goodley, 2005) and is the term used by many local authorities in the UK which deal with LDs.

However, we are of the opinion that various initiatives in society to address a spectrum of needs for each individual in a LE, by detecting Differences In learning (DiffInL) is a much better term, which may be used in this research. There are not so many peer-revived sources which debate a distinction between LDif and DiffInL, however the reader is advised to look at the (Millman & Ritte, 2006) where the authors emphasise why the LDif is a wrong term in LE.

Historically, most peer reviewed papers from the 90s onward used only LD. The literature review has discovered that changes form LD to LDif was initiated within various government bodies in the world and the perception in western society that the word 'disability' is not appropriate and might be offensive for individuals who cannot exhibit progress in the classroom as expected.

Whilst people with LDif may not have a particular disability (e.g. dyslexia), people with disabilities might, or might not have any LDif.

Throughout this document the term LD will continue to be used, because there are simply no research papers which use the term DiffInL.

However, (OB1) will not change, and the researcher will try to prove through the (OB2) and (OB3) that DiffInL should take central stage when addressing the modern LE. Furthermore, given that the differences between these terms are so subtle, it may be impossible to answer the questions:

1. how many of us have experienced DiffInL in our lives?
2. Are learning processes always 'smooth', even for people who cannot or do not wish to declare any LD, LDif or DiffInL?

2.2 LD common types

The common types of LDs are usually those that have impact on school area skills sets, including reading, writing, and maths skills. They may be complicated by the addition of other disorders that effect attention, behaviour, or language, but they are diverse in their impact on learning ability. In the following subsections some of these common types are explained (Browder & Cooper-Duffy, 2003) (Goldsmiths University, 2011) (Thakran, 2015).

2.2.1 Dyslexia

Dyslexia is a type of LD that stems from processing difficulties, which affect reading, writing, spelling, memory, and organizational skills. It affects approximately 10% of the UK population. According to Horowitz, the Director of LD Resources National Centre for Learning Disabilities, it is *"... the most prevalent and well-recognized ... specific learning (disability)"* (Cortiella & Horowitz, 2014).

The dyslexic learner is usually described as having a 'spiky profile' which means that their speaking and reasoning skills are often average, or above average, whereas their writing and reading skills can be significantly depressed in comparison. It is a spectrum, which means that every individual has a different and unique set of processing difficulties. Reading can be affected in two different ways:

Firstly, processing difficulties can affect reading skills at the base level, e.g. learners may have difficulty discriminating the relationship between speech sounds, letters, and words.

Secondly there may be difficulties with reading comprehension (i.e. understanding the meaning of individual words, phrases and paraphrasing).

However, the common signs of reading difficulties are problems recognizing either individual or clusters of letters and words, understanding the meaning of words and ideas, reading rate, fluency and overall vocabulary skills (Campbell & Butterworth, 1985) (Cline & Reason, 1993) (Woodfine, Nunes & Wright, 2008) (Rapcsak et al., 2009) (Penney, 2012).

2.2.2 Dyscalculia

Dyscalculia is the term associated with specific learning disabilities in maths. Although features of LD in maths vary from person to person, common characteristics include: difficulty with counting, learning number facts and doing maths calculations, difficulty with measurement, telling time, counting money and estimating number quantities, trouble with mental arithmetic and problem-solving strategies (Gross-Tsur, Manor & Shalev, 1996) (Landerl, Bevan & Butterworth, 2004) (Price et al., 2007) (Piazza et al., 2010) (Menon, 2016).

2.2.3 Dysgraphia

Dysgraphia is the term associated with specific learning disabilities in writing. It is used to capture both the physical act of writing and the quality of written expression. Features of learning disabilities in writing are often seen in individuals who struggle with dyslexia and dyscalculia, and will vary from person to person and at different ages and stages of development.

Common characteristics include: tight, awkward pencil grip and body position, tiring quickly while writing, and avoiding writing or drawing tasks. Learners with dysgraphia also can have trouble forming letter shapes, as well as inconsistent spacing between letters or words, difficulty writing or drawing on a line or within margins and trouble organizing thoughts on paper (Campbell & Butterworth, 1985) (Caramazza et al., 1987) (Rapcsak et al., 2009) (Fletcher-Flinn, 2016). They can also experience trouble keeping track of thoughts already written down, and have difficulty with syntax, structure and grammar.

2.2.4 Dyspraxia

Developmental Coordination Disorder (DCD) is commonly known as dyspraxia. It is a learning disability, which affects gross motor coordination and/or fine motor skills in children and adults. This is a spectrum, and individuals will experience a unique set of difficulties to do with their coordination and processing. Symptoms can include difficulties with organising ideas, putting ideas onto paper, motor skills such as writing and typing, sports such as cycling, where balance is key and sometimes domestic skills, e.g. setting the table or stacking a dishwasher, which some dyspraxics find confusing and challenging. Some learners with dyspraxia can find it difficult to access further and higher education and employment due to their difficulties (Alfrey et al., 1972) (Cermak, 1985) (Alcock et al., 2000) (Mostofsky et al., 2006) (Martin et al., 2015) (Gonzalez Monge, 2015).

2.2.5 Attention Deficit Disorders and Attention Deficit Hyperactivity Disorder (ADD/ADHD)

Attention Deficit Disorders and Attention Deficit Hyperactivity Disorder (ADD/ADHD) is very common in childhood and often continues into teenage years and adulthood. Learners with ADD/ADHD have problems retaining their focus, they tend to be hyperactive and have difficulties working in a group as they struggle to control their behaviour (Shimabukuro et al., 1999) (Connor, 2012) (Romo et al., 2015). This presents a real challenge for educators, in terms of finding a learning programme, which suits their needs and keeps their attention.

2.2.6 Autism

Autism spectrum disorder is generally known as ASD; once again it is a spectrum and includes Asperger Syndrome and childhood autism. It is a lifelong problem that affects communication skills, social relationships, behaviour and interests.

In general, they symptoms of ASD begin in childhood but are not always recognised until the person has a life event, which signifies a major change for them, for example a change of house. Approximately 1% of people in the UK have ASD. The condition does not have any known ‘cure’, and a number of treatments have been developed. However, they all focus primarily on behaviour modification.

Although all of these LDs differ, there are some commonalities in terms of information processing difficulties. These include processing information, memory difficulties, expressing ideas – especially in writing, and difficulties with sequential learning (Tjus, Heimann & Nelson, 2001) (Kjelgaard & Tager-Flusberg, 2001) (Williams et al., 2002) (Iovannone et al., 2003) (Odom et al., 2003) (Simpson, 2005) (Dawson, Webb & McPartland, 2005) (Millman & Ritte, 2006) (Mostofsky et al., 2006) (Pinborough-Zimmerman et al., 2012) (McCollow, Davis & Copland, 2013). These difficulties can cause the learners to undervalue themselves, have a lack of confidence and feel frustrated. They can also lead to social isolation and under-performance, in terms of their real potential.

2.3 The Demographic of People with LDs

It is difficult to find a conclusive report regarding the exact number of LD people within the UK; however, it is possible to estimate this number with reference to a combination of sources. These sources include government records of LD people using particular services, overall population, and epidemiological research results. According to (Ngao, 2006) (Emerson & Heslop, 2010) (Emerson & Baines, 2011), the overall estimated number of people with LD was 1,191,000. This information was classified into categories based on age and gender. There are 286,000 children with LDs, 180,000 of which are boys. The estimated number of adults whom are over 18 was estimated to be 905,000 and the majority of these were also men (530,000). This data suggests that the incidence of LD is more common among males than females.

Approximately a quarter of a million of children are at the School Action Plus (SA+) phase of assessment of Special Educational Need (SEN), or have an SEN statement. 2.8% of these have a primary SEN associated with LD (17%) (Emerson & Baines, 2011) Of these, 89% are categorised as moderate LD, 24% are severe LD and 18% are deep multiple LD (Emerson & Baines, 2011).In addition, analysing these estimated figures revealed that the largest group of pupils with SEN statements fell under the category of autistic pupils and those with moderate LDs (Emerson & Heslop, 2010) (Emerson & Baines, 2011).

2.4 Supporting Technologies for LDs

Research has shown that technology has proven to be an effective method of giving learners with LD opportunities to engage in basic drill and practice, simulations, exploratory, or communication activities that are matched to their individual needs and abilities (Ahmad et al., 2010). There are numerous examples of the use of hand-held devices of various computational and communication power, smart whiteboards, pens, tablets and similar which address the needs of students with LD in their learning process (Ngao, 2006) (SMART Technologies, 2006) (Schreiber, 2008).

There are also software solutions which create tools for a variety of tasks that a disabled person may perform during the learning process (Savoie, 2008) (Deubel, 2008a) (Deubel, 2008b). This area of research does still have an open door to creating new solutions for LE which satisfy needs of modern educational systems and include people with LD into main stream education (Peters & Rosson, 2008) (Al-Ajlan & Zedan, 2008).

Students with learning disabilities face several challenges in their schools especially in tasks that require writing, reading, listening, speaking, and thinking skills (Spekman, Goldberg & Herman, 1992). The majority of LD students have reading difficulties in association with incomprehension and fluency (Humphries et al., 2004) (Therrien & Kubina, 2006), word recognition and word decoding (Sperling, 2006).

A study by Vaugh et al., (2002) also revealed that more than 90% of LD students are struggling to read independently. For example, autistic students usually have insufficient reading skills due to them taking part in less reading activates, their mobility anxieties and their limited ability to make conversation and ask questions (Martin, 1977) (Tjus, Heimann & Nelson, 1998) (Mastropieri et al., 2001) (Williams et al., 2002) (Vaughn et al., 2002) (Browder & Cooper-Duffy, 2003) (Basil & Reyes, 2003) (Englert et al., 2005) (Sperling, 2006) (Therrien & Kubina, 2006) (Vernon-Feagans et al., 2012) (Hollenbeck, 2013) (Cirino et al., 2015) (Klingner, Vaughn & Boardman, 2015) (Coleman-Martin et al., 2005).

The involvement of technologies in learning has positive effects on the achievement of LD students, as it allows them to compensate for their deficiency in requisite skills and allows them to access information that was previously inaccessible (Fichten, Barilee & Asuncion, 2003) (Woodfine, Nunes & Wright, 2008). As well as the processing difficulties experienced by LD learners outlined in the paragraph above, they have an additional barrier to face in terms of regular attendance and challenges in maintaining concentration. For these reasons, they need a flexible way of accessing materials.

Traditional teaching has the advantage of a direct human interaction between the learner and the tutor, however this scenario does not work in the case of students with disabilities mentioned who are unable to attend schools or colleges regularly. Health issues can mean that a child has to spend periods of time in hospital, wellbeing issues, such as mental health difficulties can mean that individuals also have erratic attendance. These students would therefore benefit greatly from innovative and flexible ways of accessing information and e-technology offers an effective solution. It means that they can find the subject that was taught in class whilst they were unwell, and choose their own time, when they are feeling better able to concentrate. It therefore allows not only for more accessibility, but also more individual choice and more inclusivity and awareness of individual differences.

Once again, learners with ADD/ADHD who have trouble concentrating for long periods would be able to work with their tutors to agree more realistic timetable, with regular breaks factored in. The new e-technology can be used either independently, or in partnership with traditional teaching to improve the quality and scope of education and encourage learning for life (Georgiev, Georgieva & Smrikarov, 2004).

Over the last few decades, the number of people using technologies in different aspects of their lives has increased, and this trend has been successfully applied to educational sectors. Initially, technologies in education were utilised for teaching typing and word-processing, however since then computers and various associated software evolved dramatically through the use of online materials and this has made education accessible to numerous students worldwide (Sun et al., 2008).

The utilisation of IT (e.g. the electronic blackboard, micro/earphones and so on) for learning purposes to enhance the educational process is known as ‘electronic learning’ (e-learning), and this can be delivered by various educational institutions to both local and distance-learning students (Sun et al., 2008). This form of education has gained popularity among learners and enabled thousands of students to benefit and gain their qualifications each year (DfEE/QCA, 1999).

Mobile learning is another use of technology in learning, and it includes mobile devices such as cellular and smart phones, notebooks, PDAs, and tablet PCs. Mobile learning is used in association with wireless to create the main platform, which facilitates and delivers many learning experiences through web browsing and/or bespoke software (Liu et al., 2003) (Georgiev, Georgieva & Smrikarov, 2004).

In the UK, a collection of technological products is used to teach students at schools, based on task transferable skills (DfEE/QCA, 1999). Nowadays, schools and universities have their own network system that connected to central servers or LANs allowing access and use of variety of applications (BECTA, 2007). There are also a huge number of interactive applications and games available online that assists various learning styles through the using of different types of media as texts, audio, and images (Franken-Wendelstorf, Konrad & Schuchardt, 2014).

The extensive use of Internet and web-based technologies has significantly improved the way students can manage their studies using educational technology (Moeller & Reitzes, 2011). The advance of technologies has not just facilitated the immediate access for educational information but it also provided students with many communication systems and dedicated learning environments.

E-resources can either be used by individual learners alone, or they can also be used by a teacher, in a traditional classroom setting, who makes the link for students so that they can access online materials, whilst having a professional at hand to help them. This is known as "Blended learning". According to the Cambridge online dictionary, blended learning is "a way of learning that combines traditional classroom lessons with lessons that use computer technology and may be given over the Internet".

Although blended learning involves the physical presence of a teacher/facilitator it still breaks barriers in that it allows for a situation where every student could be working on their own tailored learning programme, at the same time.

There are two types of commonly used communication systems in blended courses; these are known as synchronous and asynchronous. Synchronous communication is like a conversation in which students activities take place in real time (Sotillo, 2000). A chat session is an example of a synchronous activity, allowing individuals to get online at the same chat room and type questions, responses, and comments in real time. Synchronous activities may involve audio and video feeds to computers. Some online courses require conference call and closed circuit television links as synchronous tools to allow the learner and the teacher to get together personally (Allen & Seaman, 2004) (Allen & Seaman, 2007). In contrast, the activities in asynchronous communication take place outside of real time, such as discussion boards in which learner can post a message or email with his/her question and comments and other members can read and reply over time (Sotillo, 2000). Conversation and replies are all related and students can join in at any time and from anywhere that is convenient for them (Allen & Seaman, 2004). Viewing videos or reading a textbook linked to the course site are also a type of asynchronous activity.

In the next subsection a snapshot of various projects is given, which illustrates how technologies can be used today to address needs of learners with LDif.

2.4.1 Use of Technologies Supporting LD

Ismail et al., (2009) propose a specific Block-Based Software Development method which can be used by parents and teachers to support pre-reading and pre-number skills in autistic children (Ismail, Omar & Zin, 2009).

A framework of an interactive semi-virtual environments is proposed in (Konstantinidis et al., 2009) which can enhance a learning environment for children with autism. The authors advocate that such environments can increase the learning attentions for longer time than in a normal classroom and therefore addresses slow learners' teaching-learning situation (Abdollah, Ahmad & Akhir, 2010a) (Abdollah, Ahmad & Akhir, 2010b). In Harrison et al., (2008) there is an interesting analysis of the role of interfaces in virtual environments, such as Second Life (Warburton, 2009), which can significantly affect a learning experiences of visual, hearing and motion impaired students.

Many initiatives to use interactive and audio based multimedia software for children with visual disabilities are available, such as (Szeto & Christensen, 1988) (Harrison, Stockton & Pearson, 2008) (Sanchez & Flores, 2010) (Toennies et al., 2011).

Interfaces are also examined for cognitive and learning disabilities in (Fryia, Wachowiak-Smolikova & Wachowiak, 2009) as a way of removing barriers between disabled learners and many e-learning systems available today. Interactive technologies are known to help the rehabilitation and learning for anyone with disabilities (Gold, Wigram & Elefant, 2006) (Gal et al., 2009), but the idea behind using concepts mapping for virtual rehabilitation and training of blind in (Velligan, Kern & Gold, 2006) (Sanchez & Flores, 2010) is very impressive. They designed and evaluate the use of audio based concept mapping tool which help blind users to construct concept maps to improve the presentation of their knowledge and learning capabilities. It has been known that music therapy helps in various rehabilitations for children and adults, but the work of (Correa et al., 2009) promotes augmented reality musical system to address the needs of children with cerebral Palsy.

In (Wan, Wang & Haggerty, 2008) and (Ahmad et al., 2010) game-based learning courseware for children with LDs can be found, which stimulates their psycho-motor for using the computer and develop their thinking skills while playing games. They claim that their experiences might influence the future perception on how a LE for student with LD can accommodate gaming activities for the purpose of learning. They are focused on real world objects and virtual environments equipped with avatars to provide emotional feedback which assists in collaborations with students. Musical notes are associated with the cards played in this environment and therefore any physical disability of a child does not have to be an obstacle when playing an instrument.

2.4.2 Dedicated Learning Environment

The Internet revolution and the emergence of different web applications and browser has contributed to the learning environment becoming a phenomenon within education, in terms of the possibilities it offers (Dagger, Wade & Conlan, 2003).

Dedicated learning environments such as the Virtual Learning Environment (VLE) and Intelligent Tutoring System (ITS) are both web-based learning systems, which facilitate learning and teaching through enabling flexible accession to different online resources, students-teacher communication, and students-materials interaction (Dagger, Wade & Conlan, 2003).

2.4.2.1 VLE in Support of LD

Section 2.4.1 listed a snapshot of technologies which are today associated with someone's attempts to learn in spite of his/her disabilities. All these examples are heading towards more sophisticated LEs where technologies are of the utmost importance! In other words technologies are driving force behind solutions which address LD and LDif in LEs.

In the last decade the LE has been transformed into e-learning (Welsh et al., 2003), virtual learning (Dillenbourg, Schneider & Synteta, 2002), immersive learning (De Freitas & Neumann, 2009) (De Freitas et al., 2009) and ubiquitous learning (Su et al., 2008). All these types of learning are associated with their own LE and VLE happens to be dominant. However, the problem is that there is no general agreement in the computing community and in education on what exactly VLEs are and too many of us are still overloaded with traditional communication tools which enable us to share materials in the classroom and "talk" to students, for example in the case of Blackboard environments.

The VLE is a computing-web based system that contains a set of learning and teaching designed tools and materials to enhance a student's educational achievements (Wilson, 1996) (Wilson & Whitelock, 1997) (Newland, Pavey & Boyd, 2003-2005) (Newland et al., 2004). Since the VLE has helped in managing computer-based learning courses, the term is commonly used interchangeably with Learning Management Systems (LMS) (Britain & Liber, 2004) (Simkova & Stepanek, 2013).

The main components that the VLE delivers and offer to students are assessments and marking, curriculum mapping tools, student tracking, collaboration tools (e.g. forums, electronic diaries and calendar), and access to outside recourses via online links (Piccoli, Ahmad & Ives, 2001) (Britain & Liber, 2004). This wide range of properties enable the presentation of an environment that is rich with learning experiences for both full time students and distance-learning students.

The beneficial aspects of the VLE, for both students and teachers has been documented in many research studies, one example is the flexibility in accessing material from anywhere, anytime (Jacobsen, 2000).

Improvement of students' motivation and engagement is another benefit, as is the flexibility it allows when presenting online materials for higher education level students, who are more independent learners and are able to work in a variety of different learning environments (Wilson, 1996) (Wilson & Whitelock, 1997) (Watts & Lloyd, 2000) (Watts & Lloyd, 2001).

Three further advantages of the VLE are that it encourages teachers who are more passive to make a greater contribution to the teaching process (Tanner & Jones, 2000), and increases performance and participation through using online seminars (Pilkington, Bennett & Vaughan, 2000) and increases self-study by sharing personal experiences and views (Russell, 2000). The VLE also enables parents to play a more active role in their child's education, by allowing them to work in partnership with the school community. They are able to access the VLE to effectively monitor their child's progress and have a meaningful, ongoing dialogue with tutors (Watts & Lloyd, 2000) (Watts & Lloyd, 2001).

A number of commercial and free VLE software products are available, each of which are similar in the functions that they perform and the material they deliver, however they may slightly differ in the working process. The most commonly used VLEs are Blackboard, WebCT (which was acquired by Blackboard in 2006), Moodle (Weller, 2007) and bespoke systems that are usually developed by different organisations to suit their own specific requirements.

Merlin, Bodington, and COSE have been developed and adapted by many UK universities and within various other sectors; and SAKAI has been established in the USA (Britain & Liber, 2004). All VLEs are governed by international standards which help to decide on the content which is made, e.g. Sharable Content Object Reference Model (SCORM) and assessments e.g.; Question and Test Interoperability (QTI). This allows for information to be made, used, and exchanged, in different VLEs.

The idea of labelling a LEs supported by tools such as Blackboard as 'a VLE' is very wrong because it does not secure the VIRTUALITY of anything in a LeS, except the exchange of data and information. However, these 'traditional' VLEs (if this label is used) are improving daily and numerous research initiatives can be found which bring forward novelties in the learning process while using VLEs.For example, Alaba et al., (2009) proposes a platform which can be used by students to connect remotely via internet to Programmable Logic Controllers (PLC), which controls their virtual learning process (Zouaq & Nkambou, 2008) (Alaba et al., 2009) (Zouaq, Nkambou & Knowledge and Data Engineering, 2009) (JISC infokit, 2004-2006) (Simkova & Stepanek, 2013). This would help to share computers and PLCs even in different locations.

JISC infokit, (2004-2006) describe their 'infoKit' which secures a working understanding of strategies of use for creating e-learning in order to meet a range of pedagogical, practical and social needs within courses of study (JISC infokit, 2004-2006) (Simkova & Stepanek, 2013). Study of (Stiles, 2001) is focused on a particular VLE, named Creation Of Study

Environments (COSE) which has been developed by The Learning Development Centre, at the Staffordshire University, UK. Their COSE has 'distributed' nature, thus the learning can take place 'anytime, anywhere'. COSE provides tools that allow tutors and learners to organize personalised learning: learner's own constructs can be placed in context with other resources and re-used or shared with peers or a tutor.

However, none of the solutions highlight the role or power of VLEs in the learning process for LD and LDifs. If it is taken into account that both of them are today mainly addressed by technologies then it is very wrong to assume that VLEs are the answer to modern classrooms, especially if the flexibility to include a set of technological solutions, on an ad-hoc basis does not exist - to support a learning process for anyone, including students with LDs.

2.4.2.2 ITS in Support of LD

As another dedicated learning environment (Intelligence and Tutoring Systems) ITSs allow students and users to view and print lectures, notes, or timetables; they also include a chat room allowing communication and the posting of messages, and offer many other useful interactive tools (JISC, 2008). An ITS utilises both artificial intelligence and expert systems to provide personalised tutoring for individuals. Such systems are highly dependent on learner knowledge, the subject and delivering strategies (Wenger, 2014). An example includes ELM-ART and REDEEM that have effectively been adapted by various educational sectors (Brusilovsky, Schwarz & Weber, 1996) (Ainsworth et al., 2003). Thereby, the pupils can register online at any training workflow; training resource management, online assessment, and the management of continuing professional growth will all be available for those users (Kozhevnikov, Hegarty & Mayer, 2002) (Avgeriou et al., 2003). Even though the adaptation of Assistive Technologies (ATs) in schools is a relatively new experience, adaptions of such technologies for students with LDs have already been seen.

2.4.2.3 Collaborative Learning in Support of LD

The computer Computer Supported Collaborative Learning (CSCL) is one of the most effective systems for assisting LD students who face difficulties with social interactions and Maths, common difficulties that have been outlined above. CSCL supports peer tutoring in different educational organisations (Mastropieri et al., 2001) (Webb & Mastergeorge, 2003) (Yip, 2004) and (De Smet et al., 2010) it is a pedagogical method that acts as a sociable learning environment (Stahl, Koschmann & Suthers, 2006). This approach is characterised by information sharing and knowledge construction between users via computer and the Internet.

Nevertheless, it can take place at using synchronous or asynchronous communication tools. An example of this can be seen in the CSCL system developed by Yip (2004), based on peer tutoring strategies to support students in facilitating communication and face-to-face discussions. This system was further improved and developed by Tsuei (2014) to meet the needs of LD students in enhancing their mathematical skills. Since the system is an integrin of synchronous CSCL, it facilitates peer-tutoring activities in maths using a multiplier online game. The author called the system G-Math Peer Tutoring System (Tsuei, 2014).

Another example of technology which supports LD learners in the VLE was developed by Hwang et al., (2009) They developed a multimedia whiteboard to support LD students in mathematic skills. They were able to do this because computer-based learning environments support translations of cognitive symbols. The system they developed contained drawing and editing tools, as well as having an online automatic saving property that allows students and teachers to discuss maths solutions and to have critical discussions about learning progress face to face (Hwang et al., 2009). The use of VLE scheming with an interface graphical user helps build mathematic knowledge by providing interactive and virtual elucidations of dynamic materials (Moyer, 2001) find more recent ones. Thus, innovations in technology for the VLE or any other dedicated learning environments have significantly changed and improved the learning experiences of LD learners, giving them more choice and a voice in the decision making about what they can learn, and when. This creates a much more flexibility platform and offers a greater opportunity for positive social online interactions. It has also allowed for flexible solutions such as blended learning, which has enabled both parents/careers and tutors to monitor and support the learner in partnership.

2.5 Modelling the Semantics of Learning Environment

In order to assess the feasibility of developing LE with individualised LeS, the research of this project has to create their own mechanism of managing semantics of any LeS and find out if the needs of students with LDif within them, are to be accommodated. Managing the semantics involves two factors:

- Defining and storing the semantics of LeS within a repository and
- Reasoning upon the stored semantics in order to address the configuration of a LeS.

In this section there will be a briefly overview of the study which is focused on a) and b) above and a specification of a LE as outlined in (a)-(d) from the Introduction. Furthermore, we knew that there are no generic software solutions, or applications, which manage the semantics of LeS, therefore it was important to choose a proper technology which helps to implement computational model which configures LeS and LE in general. Consequently, OWL/SWRL enabled environments which have been used for managing the semantics of pervasive spaces (Koay et al., 2009) (Koay, Syal & Juric, 2010) (Koay, Kataria & Juric, 2010) (Shojanoori, Juric & Babak, 2010) (Koay, Syal & Juric, 2010) should be the starting point when creating computational spaces for this research. LE is a pervasive space, by no doubt, because it comprises all: people, technologies, and services, with mobility, wireless communications and computational power (Thomas, 2005) (Shen, Wang & Shen, 2009).

It is important to note that there are no published domain ontologies, which describe the semantics of LE and LeS in any literature. In other words the researcher could not look at any existing attempts to formulate the formal semantics of LE with formal languages like OWL. However, this is not of a particular concern, because of two reasons: **Domain specific** and **formal ontologies** are difficult (if not impossible) to use in modern software applications which require certain performance characteristics in terms their ad-hoc creation, responsiveness to the environments where they reside (LE and LeS) and flexibilities of their implementations on wireless and mobile and devices.

In this research the authors does not work in the field of knowledge based systems where domain specific ontologies could bring up more experiences when designing the ontology. The model does not build a knowledge base and does not create any persistence which grows proportionally to the level of inference mechanism defined upon the ontology. In contrast, the ontologies proposed are relatively small with:

(i) only a fraction of individuals asserted (which is very important to remember) and

(ii) probably all results of inference deleted, after the application is run, are created upon the ontology.

2.6 Semantic Web Technology

Following the advent of the semantic web ontologies have emerged as the accepted standard knowledge representation technology, together with the Semantic Grid and also the Semantic Web Services. Ontologies have now become the central technology for the many emerging research branches; they are useful in that they offer a shared understanding of a domain. This standardisation lessens the chance of differences in terminology. If two applications used the same term with a different meaning, this could be problematic. However, if this occurred, the difference could be eradicated through applying concepts stemming from different ontologies, in a process which is generally known as mapping.

Ontologies will be represented through the use of the Ontology Web Language (OWL) within this study, (http://www.w3.org/2001/sw/WebOnt/), as recommended by the World Wide Web Consortium (W3C) for the exchange of ontologies for web users. OWL as a system facilitates the separation and clear definition of classes' hierarchies; it allows the user to clearly see the relationship between these classes and subsequent subclasses. It also provides a clear picture of properties and associations between classes, properties domain and range, class instances, equivalent classes and restrictions, etc. The structure of OWL is frame-like, and within it the collective data about any particular class or property can be presented in one big syntactic construct, as opposed to it being separated into several atomic chunks to make it more accessible to the reader.

There are a range of facts and axioms within an OWL ontology, and there is also reference made to other ontologies which are considered to be integrated with this same ontology. A URI (Uniform Resource Identifier) can be used to reference OWL ontologies (or web documents). There is a non-logical component to ontologies, where the designer can register their name, as the creator of the programme, and other non logical information can also be recorded here. There are a number of languages within OWL, and these vary according to how complex the constructions are. Examples of these languages are Full, Lite and DL. The latter is particularly useful in ontologies, as reasoning mechanism can be used in Description Logics. Ontology editors, for example, Protégé (http://protege.stanford.edu/), will support OWL.

Protégé is an integrated software tool that domain specialists and system developers use in order to produce systems which are knowledge based. The domain concepts, their attributes and the relationships between the concepts, are all included with the model Protégé, which is a prototype of a specific knowledge domain field. This is presented as a group of classes with linked slots. The Semantic Web is a highly effective platform when institutions wish to implement learning systems, such as the VLE. They provide the necessary sub-frame and inherent mechanisms needed to develop ontologies for learning. They also allow for materials to be annotated semantically and give the opportunity for educators to evaluate their practice. Although OWL is currently being used to a degree, there is still a lot of research to be done in terms of managing the semantics of LEs to accommodate students with LDs using SWRL enabled OWL ontologies and this study will concentrate on this.

Visionary Tim Berners-Lee presented his proposal on how to annotate documents in the Web in 1989. The links between the nodes on the web describing how they are connected together was his proposal on how documents in the web are connected. For example, if Eiman has a profile on the internet and her thesis, which is about a reference computational model for LD, once it is defended, will be available online can be annotated as shown in

Figure 2.1. In the diagram, 'wrote', and 'proposes', link these nodes. Broken line arrows show links with other nodes.

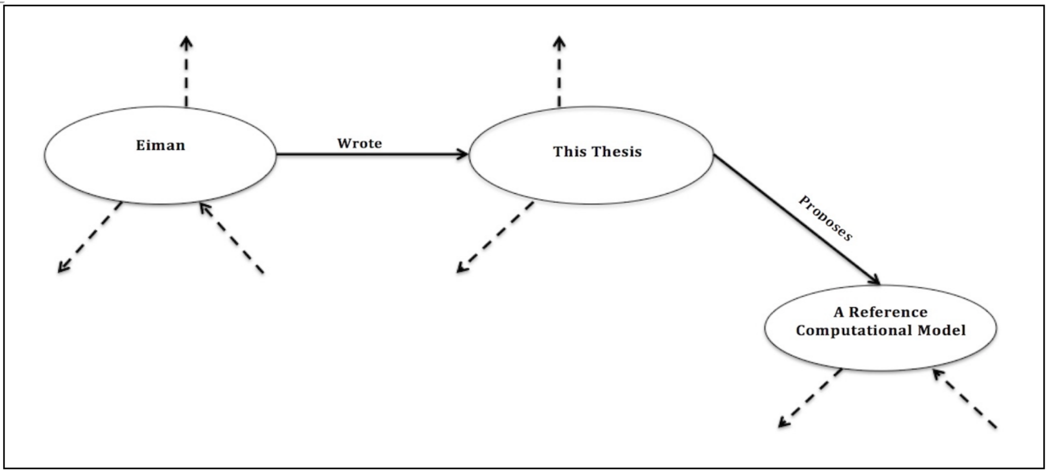


Fig. 2.1 Annotation of nodes example to link documents in the Web

The motivation for his proposal was increasing amount of unstructured information in the company's intranet network which was not supported by any meta data. Tim Berners-Lee was proposing that his idea will improve collaboration between different departments and staff as they would have more information about each document they access. The immediate solution to the HTML (Hyper Text Markup Language), HTML-encoded Web was XML (eXtensible Markup Language) technology (W3C).Although the design objective of the new language was encoding for machine processing, it does not have the necessary sound formalism to provide meaning of the terms, for example, 'wrote', and 'proposes' are meaningless to a machine processing the XML code. In other words, XML and XML-Schema could not attribute meaning to tagged terms of a document to be able to share knowledge. However, the other issue with XML was that it could only tagged the internal content of a document and therefore external sources linked to a document could not be represented. To address this issue the RDF (Resource Description Framework)(W3C, 2004c) was promoted. RDF is graph-based and comprised of nodes and edges. Each edge is a binary relationship between two nodes. The complete graph is a set of binary statements based on XML syntax. The structure of each statement is a triple: subject, predicate, object. The structure, therefore, provides a data model represented in triples. Subjects and objects are the nodes and predicates are the edge linking subjects to objects. Subjects and predicates are URI resources but an object can be either a URI resource or literal values. So, when the Semantic Web (Berners-Lee, Hendler & Lassila, 2001) was introduced XML and RDF technologies were already available.

Tim Berners-Lee's and his colleagues' vision about the Semantic Web was to improve the traditional Web so that the huge amount of information available in the Web can be shared. Enterprises, businesses, public offices, health centres, or individuals can then be strengthening by exchanging and sharing their knowledge with each other. To this end, XML, RDF and RDF-Schema were not sufficient. The philosophy they were advocating was a 'Web of data' that is structured and formalised to be processed by computers. Given that XML and RDF was both machine processable and available at the time, any new formalism had to be based syntactically on these technologies.

To ascribe meaning to sources of RDF triples, Berners-Lee et al. recommended the Semantic Web stack shown in Figure 2.2. Ontology layer is a key layer of this architecture. Although AI community has used ontology modelling for quite some time, there was no standard and guideline on use of a formal specification language for ontology. It did not take long before W3C announced its standard Web ontology language, OWL (W3C, 2004a) (W3C, 2004b) (Bechhofer et al., 2004) (Bechhofer, 2009) and only recently suggested OWL2 as the revised ontology language (Grau et al., 2008). The use of ontology in the stack is to provide vocabulary and formal meaning to concept used in the taxonomical structure of the ontology. To infer new knowledge based on existing knowledge, using ontological model, a logical rule layer was felt necessary. A compatible rule engine with OWL ontology that execute the logical rules reason about the semantics of the environment to deliver a situation-specific service. The stack depicted in Figure 2.2 Adapted from Semantic Web Stack (W3C, 2012b) also shows that any rule to support reasoning is based on ontology. Like any other technology, the rate of SW (Semantic Web) technology success depends on how widely it has been adopted by key industries. SW technologies have already started conquering various computing domains and have shown that, apart from managing

The semantics of the Web, and bringing 'structure to the meaningful content of Web pages', they can be extremely powerful for building semantics of any computational environment. Applications of (Semantic Web Technology) SWTs across domains range from business intelligence and semantic management to interoperability, communications, and data sharing. The expressive capability of OWL to allow context information to be represented for context-aware applications, on one hand, and the formalised structure of knowledge representation allowing reasoning upon acquired contextual information, on the other, demonstrated that SW technologies, including OWL, are suitable technologies for the SW requirements.

2.6.1 Ontology Definition

Ontology describes a conceptual model of certain concepts. A standard set of constructs are introduced into the representation of concepts to formalise the model. Gruber (1993) defines

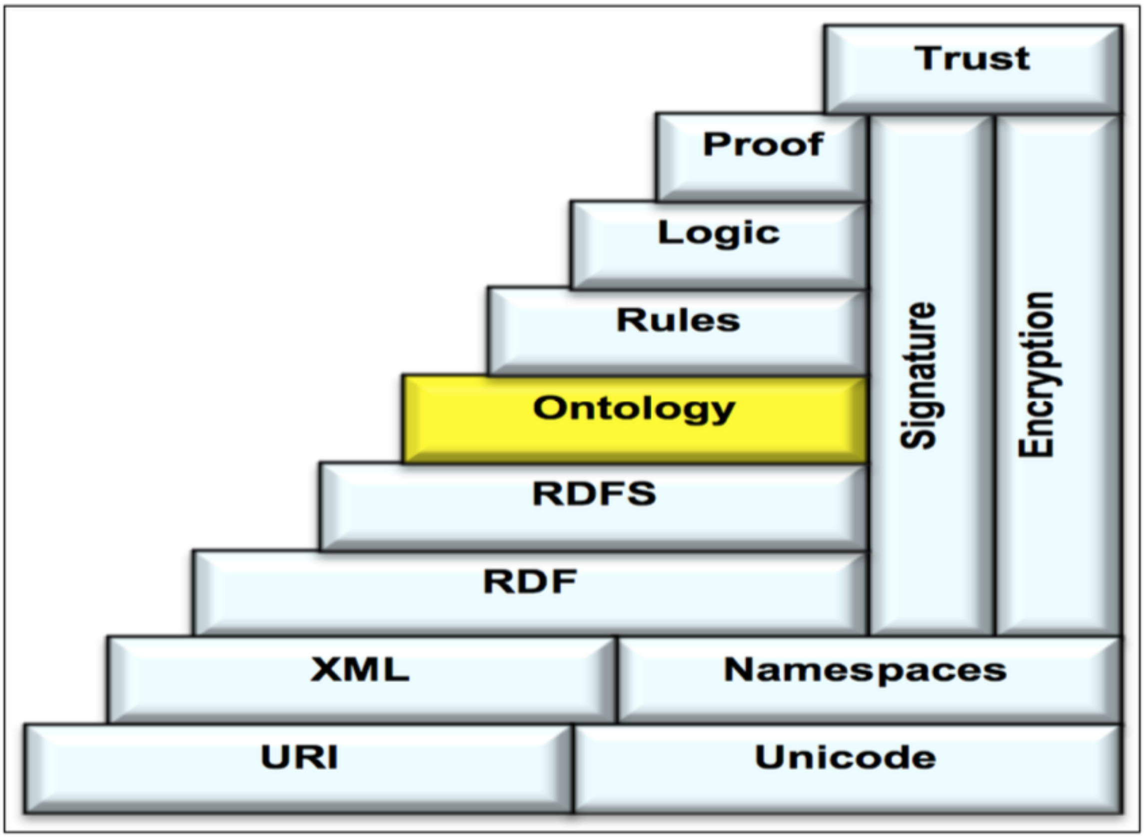


Fig. 2.2 Adapted from Semantic Web Stack (W3C 2004b)

ontology as being an explicit and formal specification of a shared hypothesis within which key concepts are recognised By 'explicit', he means that the individual concepts which make up an ontology must be clearly explained; and by 'formal' he means a formal representation language must be used in the specification. 'Shared' refers to the fact that ontology describes knowledge which has been accepted by a community (Gruber, 1993).

This common language is very important, as it needs to be clear enough to allow for the domain representation.

In addition, it needs to allow for contextual information, which already exists, to be scrutinised for any anomalies. Finally, users need to be able to use existing knowledge as a basis from which to infer new knowledge.

2.6.1.1 OWL Ontology

RDF was the first ontological language which W3C introduced (W3C, 2004c). They also recommended RDF Schema as a means of introducing some additional complimentary features, for example metadata (W3C, 2004d) (Bateman, Brooks & McCalla, 2006) (Zouaq, Nkambou & Knowledge and Data Engineering, 2009) (Gašević et al., 2005; Shi & Fan, 2009). The assertions within RDFS, as with RDF, are binary relationships.

Although RDFS has additional features to RDF, there are still decision problems in the system even though decidability is a crucial element of applications, which are based on ontologies. In order to provide users with an adequate level of support, PCE systems built on ontologies must include support for reasoning. Due to this limitation in RDFS, a new language needs to be developed.

In 2004 OWL was introduced and in 2009 it was updated to an improved second edition. Then in late 2012, the consortium W3C announced the introduction of OWL2, which they recommended for ontology language (W3C, 2012b) (W3C, 2009). With OWL1, which was the first edition, there are three variations. These are OWL DL, OWL Full and OWL Lite. The latter is a subset of OWL DL, which is itself a subset of OWL Full. Three sublanguages of OWL DL are offered within OWL2, which introduces a number of additional new vocabularies and also some new features. More information about the variations of OWL2 and Description Logic (DL) are detailed in the study by (Baader et al., 2003) (W3C, 2004e) (Baader et al., 2010) and (W3C, 2012a). Whether resources are 'subject', 'object' or 'predicate', as with RDF, they are the building blocks upon which OWL is constructed. Entities are the terminology used by W3C for resources in OWL and they are essential cornerstones when building OWL (W3C, 2004b).

The main building blocks of OWL that this thesis is interested in are 'class', 'object property', 'data property' and 'named individual'.

2.6.1.2 Constraints and Assertions with OWL

As literals are not individuals in OWL, they are not shown as a specialised type of 'Entity'. In OWL only individuals make members of an OWL class. It is worth mentioning here that although the ontology schema is represented in OWL the individuals that populate the ontology are represented in RDF.

Literals do not appear as specialised entries of 'entity' in OWL because they are not individuals, and it is only individuals which make members of an owl class. Ontology schema is represented in OWL, however individuals are represented in RDF. Two individuals who are members of either the same or a different class are linked by an object property (a binary predicate). Object properties contain two predefined properties. These are rdfs: range and rdfs: domain. The domain limits the subject of the predicate to being an individual of any given class. Similarly, the range also limits the object of the predicate to be an individual of a given class.

Listing 2.1 shows an example of an object property in RDF/XML format. In this listing object property ‘has’ is defined by its range and domain. In this case the range is ‘IMPAIRMENT’ and the domain is ‘PERSON’. According to this specification the ‘subject’ of the predicate ‘has’ is always an individual of class IMPAIRMENT, and the ‘object’ of the predicate ‘has’ is always an individual of class PERSON.

Listing 2.1 Description of an object property in RDF/XML format

```
<owl:ObjectProperty rdf:about="http://www.owlontologies.com/Ontology1382887933.owl#has">
<rdfs:range rdf:resource="http://www.owlontologies.com/Ontology1382887933.owl#IMPAIRMENT"/>
<rdfs:domain rdf:resource="http://www.owlontologies.com/Ontology1382887933.owl#PERSON"/>
</owl:ObjectProperty>
```

Listing 2.2, on the other hand, presents a sample of asserting a named individual in OWL using RDF/XML format. In this case individual ‘Hism’ that is a member of class ‘PERSON5-7’ with a number of data and object properties describing the individual is asserted. It should be added that PERSON5-7 is a subclass of PERSON.

Listing 2.2 Asserting a named individual in OWL

```
<owl:NamedIndividual rdf:about="http://www.owlontologies.com/Ontology1382887933.owl#Hism">
<rdf:type rdf:resource="http://www.owlontologies.com/Ontology1382887933.owl#PERSON5-7"/>
<age rdf:datatype="&xsd;string">7</age>
<has rdf:resource="http://www.owlontologies.com/Ontology1382887933.owl#autism"/>
<wishes_to_achieve rdf:resource=
"http://www.owlontologies.com/Ontology1382887933.owl#learning_colour"/>
</owl:NamedIndividual>
```

The Listing 2.1 and Listing 2.2 are shown in graphics in Figure 2.3.

2.6.2 SWRL Rule

When there are complicated relationships between a number of ontology concepts, then OWL ontologies are not able to offer advanced reasoning. Deductive rules are therefore introduced to compensate for this shortcoming within ontologies. SW technologies can either add structure to Web content, or they can make use of the semantics in the computational environment in PCEs. SWRL rules comprise a set of IF and THEN assertions (or premises/statements). One, or more than one premise represents the condition of the rule (or body/antecedent). One or more than one premise represents the action of the rule (or consequent/head).

Figure 2.3: SWRL rules have many uses. They can be set to implement the steps of a security system, to help the network operate more efficiently, to apply service and business policies, or to set off an early warning system which will trigger a solution/response to a particular problem in a PCE.

Although OWL ontology has a strong reasoning mechanism and a capacity for clear communication, its shortcoming is that it cannot cope when a number of OWL ‘entities’ are

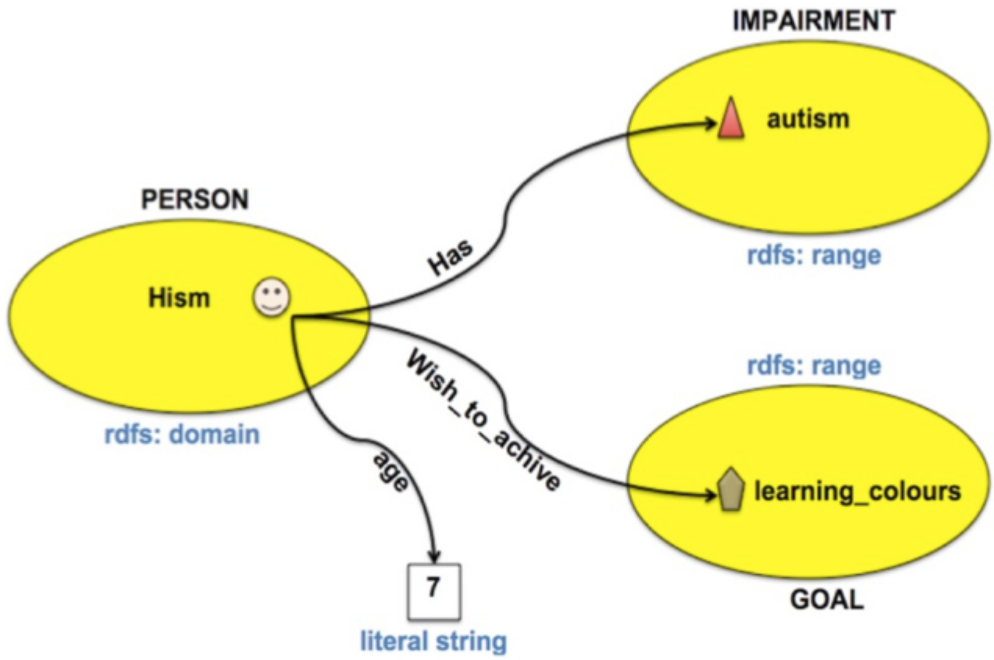


Fig. 2.3 Graphical representation of Listings 2.1 & 2.2 impairment

involved. This is a limitation, and coupled with the need for rules to be added to the ontology, that need to be run through the reasoning engine, necessitate a new language, which will enable rules to be written for the SW.

In response to this limitation and these needs, the consortium W3C recommended the use of the Semantic Web Rules Language (SWEL) (Huang et al., 2012), which would enable OWL ontology to be integrated with a rule layer sitting on top of it simultaneously (Horrocks et al., 2004) (Horrocks et al., 2005; Kataria & Juric, 2010).

2.6.3 Ontology applications

OWL ontologies are now becoming more popular and are used in a variety of domains. These ontologies are increasingly visible within the health domain where they are used to serve context aware applications as well as for vocabulary specification. An example of the latter is the Gene Ontology Consortium. The aim of this body is to produce an expressive, specified vocabulary for genetics (Ashburner et al., 2000) (Consortium, 2004) (Patadia et al., 2011) (Gupta & Garg, 2011).

Another example from the biomedical field is the production of a Thesaurus-like data base containing specialist biomedical vocabulary related to cancer research (Hartel et al., 2005).

Vocabulary specification has also been developed in a programme called SNOMED which contains a dictionary of clinical terms (Schulz, Cornet & Spackman, 2011), or addresses the requirements of a specific community, for example phenotype ontologies (Mungall et al., 2010).

The following references include examples of ontologies being used for vocabulary purposes, but then also for additional purposes, and being used in PCE applications, to serve users: (Chen, Finin & Joshi, 2003) (Chen et al., 2004) (Wang et al., 2004) (Ko, Lee & Lee, 2007) (Paganelli & Giuli, 2007) (Bardram & Christensen, 2007) (Niyato, Hossain & Camorlinga, 2009) (Polze et al., 2010) (Coronato & DE Pietro, 2010) (Arnrich et al., 2010) (Roa Romero et al., 2011) (Zhang et al., 2011).

In the case of Chen and Finin (2003) ontology was used to model contexts, using OWL language (Chen, Finin & Joshi, 2003). The authors believe that to build context-aware PCE systems, ontologies are a key consideration.

A further study was conducted by Chen et al (2004), and a Standard Ontology for Ubiquitous and Pervasive Applications (SOUPA) was developed as a shared ontology to support both UC and PCE applications (Chen et al., 2004). Their aim was to try to standardise shared ontology, so that it can be used and reused by application developers, driven by ontology. They ontological model they developed, using OWL was therefore a generic model, designed to be more accessible to a wider number of developers.

Khedr and Karmouch (2004) developed an agent-based system for negotiating context information. They chose an ontology agent which included the semantic capability to allow other agents to represent and share context in their system. They chose to take an approach based on ontology in order to represent a unified context model. Their argument for this choice was that existing approaches did not allow users to extend existing information and to link up with other context aware systems (Khedr & Karmouch, 2004).

Wang et al. (2004) produced CONtext ONtology (CONON) which contained a set of ontologies representing and describing contextual information – divided into generalised and domain-specific ontologies (Wang et al., 2004).

The model of Ko et al (2007) does not incorporate an element of time, but within its ontology based U-Health Care, three context ontologies are given: Environment, Person and Device. These ontologies, similar to those of Want et al (2004) are grouped semantically into domain context ontology and general context ontologies.

The ontological model of Paganelli and Giuli (2007) is more enhance than the model of Ko et al (2007) in that it is more detailed, containing four ontologies which represent the patients who use it; other people with whom they may come into contact, their physical surroundings and finally an ontology to manage the alarm. The physiological information of patients is contained within the 'Patient Personal Domain Ontology.'To reason upon the context the authors have employed OWL language together with first order logic rules. Ontological individuals, for example classes, are repeated in various ontologies in order to run predefined rules.

Stevenson et al., (2009) presented an in-depth, overall snapshot of ontologies used in pervasive systems. They incorporated the adaptations suggested for modelling context by (Strang & Linnhoff-Popien, 2004) and (Strang & Linnhoff-Popien, 2004), who believed it was necessary to support temporal data and capture the quality of this data. Stevenson et al., also added adaptations needed to model properties and capabilities of sensors. Their model was called the Ontonym model and included ontologies such as People, Location, Time, Device, Resource and Event. In order to evaluate a context model they suggest running the application to see how well it fits. OWL language is not used in all context management and ontology based applications (Stevenson et al., 2009).

Korpipää et al. (2003) use RDF instead of using OWL for context representation (Korpipää et al., 2003). An ontology-based context-aware system is also produced by (Jahnke, 2004). The context representation is grouped into domain independent ontology and domain dependent ontology. To store contextual data they used a graph-based database and they created their own encoding for contextual representations and to allow communication between context users and context sensors. Since the W3C consortium rubber stamped OWL as the standardised ontology language in 2004, very few developers are now attempting to create other languages.

2.6.3.1 Use of Ontology in Education

Aroyo and Dicheva (2004) state that Web-Based Educational Systems (WBES) have adapted to meet the exacting demands of educators and students. Each individual learner has a different level of understanding, depending on variables such as age, educational background, learning impairment, state of mind on the day and at the moment of study. In order to respond to the learner's needs at any given moment in time, advanced intelligent WBES is required which can adapt and respond on an individual basis. This is created by ontological structures, which enable learner models to be built; these include topic maps, concept maps and graphs which allow domain knowledge to be organised and processed in a visual form. These structures allow conceptual domain presentation to link up to the structure of the course and also a range of educational materials, which are available (Aroyo & Dicheva, 2002) (Dicheva, Aroyo & Cristea, 2003) (Aroyo & Dicheva, 2004) (Cheung et al., 2010).

Meenachi and Baba (2012) references the Sharable Content Object Reference Model (SCORM) which is based on a group of technical guidelines, specifications, standards, all designed for a system which is easy to use, allows for the sharing and re-use of data, may be accessed by a various users, and is durable (Yang, Hwang & Chu, 2005). This model is designed for the Next Generation Learning Environment of Adult Learning Environments (ADLs). He also explains how Topic Maps for e-Learning (TM4L) provides a space for the development and use of topic maps-based repositories where online materials can be accessed (Dicheva et al., 2005). A range of materials can be stored here such as books, journals, and software, working groups.

Huang et al (2006), also reference SCORM, however they believed that there were inherent shortcomings in that it did not fully support the documentation of pedagogy. Instead they suggested a different model based on intelligent semantics designed to include an ontology database. Huang et al., believed that ontology, which presented a formal set of concepts and relationships within a domain, was better than traditional SML (Statistical Machine Learning) as it incorporates relationships between data elements.

This study is concerned with matching learning impaired students to e-learning materials so the sub concepts of knowledge need to be considered, e.g. the construction and communication of knowledge (Aroyo & Dicheva, 2004).

Ontologies for the Use of digital learning Resources and semantic Annotations on Line (OURAL), refers to the field of elearning, and this covers case studies, problem solving, cyber quest, etc...(Grandbastien et al., 2007) (Xiaopeng & Xu, 2010).

Many educational systems within Europe use ontologies when they are building their resource base, for example when students from many countries are all studying for one common exam – this means that all users can access common materials, using a common language. When educational ontology is in place, they are defined by semantic web ontologies as being made up of the ontology of the person, the user profile, the contact and the activities (Bucos, Dragulescu & Veltan, 2010).

Bhowmick et al., (2007) discussed the use of Sahayika, which is a knowledge network with an interface, which allows for the building of a new ontology for subjects on the schools' curriculum This was created for the educational domain in India and through navigation; the user can browse, visualise and build ontology. Users can access learning materials for a range of courses. In the example cited, Chemistry, History, Biology, etc. are mentioned .The system includes indexing tools, which means that teachers can organise their course (Bhowmick et al., 2007). Teaching practice ontology, which is inbuilt to the system, accommodates online direct learning, course browsing, and also allows teachers to manage their courses electronically (Wang, 2011).

An added benefit is that the system allows the student to access self-learning programmes. This is currently being trialled within eight secondary schools in West Bengal, and the system supports both Bengali and English (Bhowmick et al., 2007).

The researcher of this study would like to build in a multi-lingual facility to the reference computational model in the near future, to make the system more accessible. The aim is also to allow learners to access a range of subjects, for example literacy, numeracy, Citizenship, problem-solving, etc.

2.6.4 Competency Questions

In order to develop a new ontology, or to improve upon one, which already exists, Competency Questions (CQs) need to be asked, as a way of discovering the relevant information required. These CQs will detail the criteria of the design of the ontology, namely its constraints and terminology and they are a means of checking that the ontology matches the requirements of the questions.

It is important that any set of CQs are not limited to just one specific ontological model. The particular phrases or words used to form the terminology of the formal ontology specification. Therefore it is vital that these CQs accurately and clearly capture all the requisite demands of the ontology design.

Noy and McGuinness (2001) stress that ontologies will vary and "... there is no single correct ontology for any domain" (Noy & McGuinness, 2001). The choice of ontology will be influenced by several factors. These include how the ontology will be used and how the designer understands the domain. It is only when the ontology is tested out by the designer that its quality is able to be assessed. Ontologies are tested against a set of pre-defined competency questions.

Fernandes et al., (2011) recognize the need for the clarity of CQs and observe that CQs can, on occasions, be ambiguous at the outset of research. They elucidate by saying that they are a list of questions, which give the aims, and the range of the ontology which is being developed. When the requirements engineering stage of the software process are being designed the competency questions are similar to the systems requirements. When the ontology engineer decides upon which competency questions to select, he or she can use a number of different methods(Fernandes, Guizzardi & Guizzardi, 2011).

Once the competency questions have been decided upon, they may need to be revised slightly, to ensure that they fit in with the goals of the project and how the modeling process is progressing (Sure et al., 2002). The questions will help to build the ontology by deciding upon the key concepts and ensuring that the key words appear in the questions.

Competency Questions in this study are helpful in that they address some of the current issues faced by the community, for example they can incorporate the strategic goals of an organisation, for example the goal of making educational resources more inclusive for those with learning impairments. They can also consider who is sharing these objectives, for example students, teachers, facilitators and parents. In addition they can ask valuable questions about the resources needed to help meet the community's objectives, such as learning materials and technology (Almami et al., 2012) (Almami et al., 2015).

2.7 Foresight

In this section the relevance to the thesis, of the technologies discussed above, will be elaborated on, to pave the way for the following chapters.

The reference computational model that the thesis is proposing, addresses the precise requirements which individuals need in order to overcome some learning difficulties they have, due to certain impairments.

The semantics of the influencing factors that decide which 'learning practice' should be to taken by students is an essential part of the system to be devised. These semantics are modelled through ontologies, hence section 2.5 discussed representation of concepts through ontologies.

The thesis follows W3C recommendation on ontology language and therefore in section 2.6.1.1 OWL Ontology is discussed in relatively full details. The view this thesis advocates about the use of OWL ontologies and the approach it takes is different from the ones the semantic Web technologies were originally devised for.

In this thesis the researcher uses ontologies not as a vocabulary set, just defining a set of terms. The use of OWL ontologies in this thesis is limited to specification of some of the concepts necessary for logical reasoning to take place.

Towards the development of ontologies to enable reasoning upon, it is quite important to define and represent restrictions on individuals of different ontological concepts. This has led to some background explanation in sections 2.4.1.2, and 2.4.1.3. Relating different learning practices to different goals that students with several impairments may have, requires associations between several concepts within an ontology. Representing these relationships in an ontology is a difficult, if not impossible task. Use of a reasoning engine that uses the defined semantics of the ontological model is the alternative that this thesis will follow.

The W3C recommendation for a rule language used with OWL ontology is SWRL, and that is why in section 2.6.2 this language is discussed.

After discussion of the background of learning disabilities and the technologies of the Semantic Web that this thesis is using, the researcher considered it important to include section 2.6.3 to provide an overview of the use of ontologies in various domains and particularly in education, where SWRL enabled OWL ontologies are used.

Chapter 3

Related Work

This chapter will present a detailed explanation of the research problem by going through related works. Within this chapter, recent studies will be examined and some of the problems facing LD students, in terms of accessing online technologies, will be explored. Semantic web technologies which offer solutions to these problems will also be investigated. The works of educational theorists in the field have been critically appraised for both strengths and limitations.

3.1 Disabilities Diversity and Spectrum

Disabled students present with different kinds of impairments, which may affect them in areas such as mobility, speech, hearing and visualizing. They have a variety of individual needs, which vary in severity and result in them facing diverse challenges, which are not always apparent (Alberta Learning, 2002) (Alberta Learning, 2003-2004). These needs include assessment and identification, collaboration, meaningful parent involvement, ongoing assessment, personalised programme planning, self-advocacy, transition planning, accommodations and instructional practices.

Alberta Education stresses that LD students are all unique. In recognition of this, they advocate a learning plan which caters for their specific individual needs and do not believe that they should be stereotyped and categorised as ‘disabled’. They argue against an over-simplified approach. This ethos is very similar to the ethos of the author of this project who also believes in the unique nature of each individual learner and places the emphasis firmly on the LD learners ‘abilities’ rather than creating a negative model based on ‘disabilities.’ This also takes into account the needs of LD learners with complex disabilities, recognising their potential as being paramount.

Once these components are put into place effectively, they can have a significant impact on students with learning disabilities. It was found that the LD student's progression depended on such effective programming. Other measures which positively impacted on LD students' progress included better methods of identifying LDs, an emphasis on early intervention, evidence-based practice, recognition of teen reading ability issues and improvements in assistive technology (Price, 2009).

The ideology of Price is similar to the ethos of the author of this thesis, because both believe that the best online learning system takes into account complex disabilities and individual needs, and that AT can greatly help the learner. Both the author and Price recognise that former systems have not been flexible enough, and therefore have sometimes provided a negative experience for the LD learner. They therefore are determined to find a solution which improves the learning experience which is quicker to access and caters for a whole range of different disabilities, generating individual learning plans and introducing improved use of assistive technology. (Ibid).

Disability itself is complex, and students may have a range of disabilities which do not fit neatly into categories. This gets even worse when students are facing with rare disabilities. In separate studies Steyaert (2005), Tompsett (2008) have concluded that universities are not capable to control and modify their environment to accommodate the needs of their students (Steyaert, 2005) (Tompsett, 2008). As a result, the needs of students with rarer disabilities are not being met due to the inflexibility of existing learning environments. Considering inaccessibility of learning environments and incompatibility with assistive technologies Tompsett stresses that learning environments and assistive technologies need to be more compatible allowing a unified environment which is a positive experience for the learner and is easy to access (Tompsett, 2008).

The emerging paradigm of block based development approach towards building highly customizable application software which could be useful for children with learning disabilities such as dyslexia, dysgraphia, dyscalculia, attention deficit disorder or genetic/developmental disorders like autism and downs syndrome, is explored by Ismail et al., (2009)

Ismail et el., (2009) recognize in their paper the impairments related to autism. They acknowledge that individuality of each learner and state that although there are many common factors in autistic leaners, no two learners are the same. Consequently they suggest that learners resources need to be personalized and proposed a block-based Software Development method.

According to the author, the block based approach can be considered as a combination of two approaches – Component Based Software Development (CBSD) and End-User Development (EUD). The system implementation was divided into three sub tasks. The block identification identified the necessary blocks that were required. For instance, the curriculum was divided into Gross motor skills, Fine Motor skills, Self Help skills, Language development, Reading-Writing- and early numbers and social development. Once the blocks are identified, the second stage is to implement each of these blocks.

Finally, once all the blocks are developed and individually tested, they can be seamlessly integrated as per the individual requirement using a Block Integration Tool. The model they propose, they hope, helps teachers and parents to create application software which is tailored to suit the individual needs of the autistic learner (Ismail, Omar & Zin, 2009).

Prejudices and assumptions about people with LDs are prevalent and can also be found, to some degree, within educational establishments, which are microcosms of society. Ismail et al., state that with the right support and intervention LD learners can succeed in school and go onto successful careers, and the author of this project agrees with this opinion, sharing the same view with the authors that learners with autism have a different learning style which makes using conventional teaching methods problematic. For example, it can be hard for them to sustain concentration, they may be ritualistic and take comfort from repeating the same behaviours and become upset if their daily routine changes (Ismail, Omar & Zin, 2009). Although understanding their weakness, and how to help them with these is important for parents and teachers, their strengths are often overlooked. Recognizing and working to strengths gives learners confidence as it encourages them in what they do well, and helps educators to develop useful learning strategies, from a positive starting point (Tompsett, 2008).

3.2 Equality of Opportunity for LD Learners

The main objective of educators, who are creating teaching plans, is to ensure equality of opportunity for all LD students, to enable them to fully and freely participate and become effective in all areas of their lives. Studying a number of learning and teaching strategies has been attempted by (Babu & Peter, 2011) for students with learning difficulties. The authors suggest that it is important to have a mechanism for measuring the activities that students carry out, in order to evaluate the degree to which they have improved when following the curriculum. To involve tutors giving specific, customized, directed guidelines to their students, with clear learning goals, which will permit a student with learning difficulties to take some ownership in terms of monitoring and achieving their own goals. To Babu et al., addressing learning goals of individuals ensures equal opportunity across the board (Babu & Peter, 2011).

Where this research differs from others, is in the fact that it does not have a mechanism for measuring the work that the LD learner has done. Babu et al (2011) believe that it is important for a computational model to contain a mechanism for students to measure and evaluate the learning exercises that they have completed. However, the computational model created by the author is different to the one suggested by Babu et al, because it does not contain a measuring option and a way to monitor their learning. However, this model does allow the LD learner to have a degree of independence because they are able to set their own targets and input their own learning preferences, which then generates a customised learning plan. The author recognises the value of a measuring and evaluation tool, as suggested by Babu et al., and this is part of their agenda for future research, when modification and improvements of the reference computational model take place.

The evaluation above outlines where the author's ethos is similar to that of Babu and also where it is different. In order to offer and address individualised learning, suitable practice has been developed within the reference computational model to cater for LD learners' impairments, exploiting technology.

Students with LDs behave differently in Web-based learning environments as they tend to have different learning styles from the majority of mainstream students who learn in a more sequential and reflective way. LD learners are often visual, holistic learners who thrive from using stimulating, multi-sensory materials, with clear examples and the opportunity to apply what they are learning in a practical way, through active experimentation. Popescu (2009) recognised the significance of assessing students to discover their individual learning styles, so that the online activities in their learning programmes could reflect their preferences, and so be more meaningful. She conducted an experimental study into this, by monitoring the online interactions of 75 students with the aim of analysing their learning style through monitoring their activities of moving around the programme, and selecting choices such as 'jump to page', 'jump to chapter', 'next button', etc. (Popescu, 2009).

Based on the definition of learning style introduced by (Keefe, 1979) that the composite of cognitive, affective, and psychological factors serve as relatively stable indicators of how a learner perceives, interacts with, and responds to the learning environment, Popescu, analysed learners in terms of their learning preferences. The purpose of this analysis was to ascertain whether they were visual or verbal and whether they responded better to abstract concepts or practical examples. Other preferences monitored included whether the learner was sequential or holistic, preferred reflection and observation over the opportunity to experiment actively, how careful or not they were with attention to detail, and whether they preferred to work individually or as part of a team. Popescu, research found that learning style has a marked effect on how learners behaved in online web learning environments and by extension this suggests that it is crucial to offer learners a tailored VLE which offers them the range and choice of materials which will suit them, as this will increase their enjoyment of learning and their chances of academic success.

Popescu, recognises that LD students have traditionally been disadvantaged by an educational system which predominantly teaches and assesses students through a logical, sequential, reflective curriculum. This type of curriculum is antithetical to the specific needs and the learning style preference of LD learners, whose disabilities mean that they process differently, thus leading to a disability divide. LD students have many abilities and are often of average or above average intelligence; however they do not receive validation for their skills within a restrictive, one-size-fits-all educational system which ignores their needs. In response to the injustices of the traditional education system in the UK, this research hopes that it will offer educators the opportunity of redressing the balance, by empowering LD learners. Students will be given choices, and a range of materials which are highly interactive, exciting and multi-sensory. Thus to support LD learners a shift in thinking is needed and a willingness to explore and exploit best practice in terms of online web learning personalisation. At every stage of the process the voice, choice, abilities, learning style preference and unique skill set of the LD learner will be central, with the aim of a future where every learner, even the most vulnerable, will be valued, and better placed to achieve their potential.

Along the same line (Steyaert, 2005) states that Web-based higher education is failing to transpose the basic accessibility notions from the physical to the digital environment, hence, the threat of increasing exclusion.

The needs of minority groups are often overlooked as the educational system can operate in terms of the 'survival of the fittest', offering a one-size-fits-all curriculum. This means that students who are in some way different can be disadvantaged, for example those with disabilities, many of which may be hidden disabilities.

Artiles et al., (2011) state that studies aiming "… to understand the links between culture and LD, and how culture mediates research and professional practices, have been limited and fairly recent". The authors define culture in terms of the socio-demographic markers "ethnicity, race, social class, language background, gender …" they do, however, overlook an important minority group who are also written out of research – those with LDs. Artiles et al., conclude that students within minority groups are underrepresented in studies and they wish to create an ontology for the future where LDs will improve to consider the needs of these students (Cross & Donovan, 2002). Thus Artiles et al., suggest that the current LD ontology needs to be re-framed to take into account individual needs of learners, as society is pluralistic (Artiles et al., 2011).

The reference computational model proposed by the thesis author constitutes a departure from previous models in terms of efficiency and flexibility. As highlighted above, Steyaert (2005) and Artiles et al, (2011), both comment on the fact that the needs of learners with processing differences are overlooked in most online learning environments. The author agrees with this assertion, and has put the issue of LDif students' needs at the centre of the equation, when creating the new ontological model.

3.3 Shortcoming of Knowledge Based Solutions

Zhao and Zhang (2009) give an introduction to e-learning systems, ontology technology and knowledge Management (KM) in their paper "An Ontology–Based Knowledge Management Approach for e-Learning System". They provide a presentation of an architecture for E-Learning system integrated Ontology technology and Knowledge Management (EL-OKM). Their proposed architecture consists of: Knowledge Management, Teaching Management (TM), User Management (UM), Knowledge Searching Engine (KME), Communication Tools (CT), other assisting tools, and finally a User web portal with a browser based interface.

The authors feel their implemented system could resolve the problem of traditional teaching resources, which tend to neglect semantic and knowledge concepts. There are also advantages provided by knowledge search, which is more effective than keyword search.

Zhao and Zhang's abstract are succinctly written, which means that the content is accessible to a wide audience. This is unusual in a paper about technology, where jargon is frequently used and the language is all too often complex, technical and inaccessible. Their model differs from the proposal of this thesis. They store and re-use knowledge in a data bank, because they believe that this type of ontology-based teaching knowledge serves to enhance the quality of teaching materials. On the other hand, the model presented by Zhao and Zhang is a generic one designed for all students despite their different needs, whereas the author of this thesis strongly believes that a distinct model is required to best serve the learning needs of LD students. In other words, Zhao and Zhang, proposed model is short of catering for individual needs, taking into account learning differences and preferences of individuals at any particular moment in time, tailored for one individual user (Zhao & Zhang, 2009).

Jovanović et al., (2009) in a paper on the use of social Semantic Web in learning environments explore how feasible it is for education systems in general, and for Intelligent Learning Environments (ILEs) in particular, to leverage the new paradigms for creating, maintaining and sharing the knowledge that today's ubiquitous and socially oriented services are capable of. They define ILEs as systems that rely on diverse Artificial Intelligence (AI) techniques to improve students' learning experiences, and help them to reach their learning objectives. Their research objectives are based around two features: firstly, knowledge capturing and representation; and secondly interactivity.

According to Jovanović et al., the social semantic web provides new approaches and technologies for leveraging user contribution to the system, which is achieved by means of structured information expressed with standard formalisms (ontology) that can be collaboratively created, updated and enhanced through user activities.

Within this thesis there is a very robust discussion about the limitations of the study. The authors present a series of tables with the headings of 'challenges', 'issues' and 'solutions' in which they list numerous perceived problems in depth. The paper is very vocal in terms of being student-centred right from the introduction where they discuss their main aim as being to exploit AI techniques "... *to improve students' learning experience ... (to) help them reach their learning objectives.*"(Jovanović et al., 2009).

Nonetheless, their suggestion that they have created a sound framework basis for future researchers investigating the possible advantages and implications of the Social Semantic Web paradigm for ILEs to build upon, is well evidenced. At the end of the paper, in their conclusion, Jovanović et al., once again return to the student experience, which is their 'raison d'etre'. They state that clear criteria to allow for the evaluation of social technologies still need to be developed, so that there is a measure in place to check *"... how significantly ... the application of those technologies in learning settings contribute(s) to better performance of students and/or better learning experience ... "* (Jovanović et al., 2009).

There is one main difference between Jovanović et al., system and that of the author of this thesis is that the former is knowledge based, whilst the latter is based on running rules.

The OWL technology is used for computations and not for creating the knowledge base, thus, shortcomings related to knowledge based approached as presented in (Zhao and Zhang (2009) are avoided. This system will definitely secure the configuration of the LeS without the need for consistency checking. The model has been successfully tested (Sections 5.2 and 5.3).

Another difference which is that Jovanovic et al (2009) use an ontology which is knowledge based, whereas this research does not provide a knowledge based system, the exact moment of learning is addressed and knowledge is not cumulated. Less than 40% of ontological content is actually static data. This system is based on running rules. However, there is also a similarity between the two systems, as both Jovanovic and the author are firmly student-centred.

3.4 Generic Model as Opposed to Personalised one

"A Global Ontology Space for Mobile Learning" (Benlamri & Zhang, 2008), presents a knowledge driven model for mobile learning, based on the semantic web. This knowledge model makes use of a global ontology space and a unified reasoning mechanism to integrate and aggregate knowledge describing both system centric and user centric context information. In this system, whenever context change occurs, the Run-Time Environment (RTE) identifies the new contextual features and translates them into new adaptation constraints in the results. Fuzzy Logic and Semantic Web Rule Language (SWRL) was combined to infer context that is quantized with uncertainty, and that could be inferred from ontology respectively. It also uses Mashup technology for service discovery and invocation from different distributed repositories.

The run-time environment architecture has been hierarchically divided into four levels: The lowest level is the Context Source, followed by Atomic Context Acquisition, Composite Context Acquisition and High Level Context Management sitting at the operational environment to achieve both user-centric and system-centric adaptations. This proposed approach allows reasoning with the perceived heterogeneous context elements to translate context changes into new adaptation constraints in the operating environment, thus enabling personalised learning.

When comparing Benlamri and Zhang's model with this thesis, there are a number of differences, which are apparent.

Firstly, the former model uses a global ontology space whereas the latter does not – it has a smaller, more localised ontology.

Secondly, the first model is in the inception stage and the authors clearly indicate that they still need to make significant changes in terms of introducing a variety of reasoning mechanisms, which will accommodate the specific context of the learner.

This would include variables such as their preferences and their background information. Since this study was conducted, seven years have passed, which, in terms of technological advances, is a significant period of time. In the latter, this thesis, technology is more advanced and has allowed these reasoning mechanisms to be built in, as an integral part of the system.

A third difference between the two studies, is the way that user context is gathered and the type of background information which is requested. Benlamri and Zhang adapted (Denaux, Dimitrova & Aroyo, 2005) definition of context which is *"... any information that is relevant to the interactions between a user and an environment ..."*. This incorporates such details as the conditions that surround the user, objects and circumstances. They refer to static information and give examples of this as being information such as the user's language(s) of preference, date of birth and gender. This is a fairly narrow set of information compared to this thesis, which focuses on detailed information by the user or the instructor which covers specific details about the current state of their disability and their related learning needs. An important feature of this model is that the learner himself/herself (or the instructor on their behalf) has autonomy for inputting their own personal data. This is considered to be important, as they are the expert about their own condition and needs, and also because disability status and needs can change in a short space of time, therefore this thesis model is designed to capture one particular moment in time, i.e. the specific moment they log on to any learning session – and any subsequent learning session will be different.

In Benlamri and Zhang's model it is unclear who is responsible for inputting the learner's data into the system. The implication is that it may well be inputted at some remote, online, global level, rather than at a local level. If this is indeed the case, then it could be argued that the learner is disempowered, by having generic decisions made for them.

There are a few further distinctions between Benlamri and Zhang's model and the author's model. The former is a generic one, aimed at all learners. Irrespective of their disability status, whereas the author's model is specifically designed to support LD students. There is also a difference in terms of device context, which Benlamri and Zhang define as *" ... the main source for determining the software and hardware capabilities of (the) ... devices (used) ..."* their study focuses solely on mobile phones, whereas the author's model is designed for use on a variety of technologies, e.g. mobile phones, desktop computers, iPad's, androids, etc. (Benlamri & Zhang, 2008).

There is one final point concerning Benlamri and Zhang's paper, which is a commentary on gender politics. In their user information section, they specifically ask the user to input their gender, without providing any explanation why this is required. If however, the viewpoint is taken that learning should be gender-neutral, and that no individual should be limited in their learning choices and offers by virtue of their gender, then this question should be deleted.

In the thesis of the author, when user information is requested, gender is not mentioned, as it is considered irrelevant.

Chivukula et al., (2008) attempts to address the problems faced by learning disabled individuals by adding new features such as audio/visual instruction feeds, voice/video conferencing, and text chat to the Automated Internet Measurement Lab (AIM-lab) (Fjeldly & S., 2003) (Chivukula, Veksler & Shur, 2008), which are invoked using RPI. The authors define 'Learning Disability Disorder' as a condition, which manifests itself as an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations.

The use of the word "imperfect" in this definition, with reference to the student's abilities is unfortunate, as it is a negative word and does not view the individual's 'ABILITIES';

instead it concentrates on their disabilities. Language is very powerful, and needs to be used with great care and sensitivity so that equality and diversity is respected and a positive message about every student's potential is recognised. This is important both for the student's self-esteem and confidence on their learning journey, but also for their parent/carers and the ethos of the educational establishment.

The way the programme works is that the user of an AIM-lab system interacts with the system using a web browser, which runs a Java applet, opening a new pop up GUI, requesting parameter entry. Submission of details activates a Driver Interface Layer (DIL), which in turn sends the commands to instrument driver using a General Purpose Interface Bus (GPIB). Optional features such as audio/video chats, online conferences, and message boards, would provide several channels for collaboration, depending on the learning goal.

In order for students with learning disabilities to use this system, the approach proposed by the authors is to use the Java Media Framework (JMF) or VIdeo Conferencing tool (VIC), which will make it possible to embed real time, platform independent applications into the client's browser window. A desktop Graphic User Interface (GUI) developed in Java will be designed to accommodate various learning and collaborative components. One of the benefits of this approach, recommended by the authors, is the ability of the user to customize their learning environment, by rearranging the number, positions, and size of each component in accordance to their personal learning styles.

There is a lot of discussion about the "excellence" of this system, and the many innovative features which the designers have introduced, however mention of the limitations of implementing it are conspicuous by their absence. Whilst there is mention of a facility for LD students to discuss any technical problems with either tutors, or other students, this takes the form of e-communication, in a remote setting.

LD students often experience communication barriers, in that they can find it difficult to understand instructions, and may take everything very literally, so that they become confused with what exactly they need to do in online exercises. For this reason, they would benefit from a facilitator, or an instructor being physically present in the classroom, next to them. They can then have the safety-net of being able to ask questions and get a clearer explanation, in person. Therefore, the suggestion that remote learning will make it easier for instructors is perhaps true, however, it may not necessarily be particularly user friendly for the LD learners themselves. The number of new features may also present a challenge for LD learners, who appreciate consistency and like to use very familiar systems, to make them feel safe in their learning. Thus, it would require extra staff "... to balance (their) cognitive load ..." and support students into the new system, and this would have an obvious financial implication, which has not been mentioned in the study (Sweller, 1988).

Stiles (2001) review the current trend where there has been a drive to use the technologies based around the web as a means of addressing a number of challenges which face higher and further education. The paper review particularly COSE (Creation of Study Environments) VLE which has been developed by Staffordshire University, UK. Stiles draws attention to some of the problems faced by the distributed educational systems of today. These include: Failure to sufficiently engage the learner, mistaking "interactivity" for engagement, a greater focus on content rather than outcomes, simply mirroring traditional didactic approaches on the technology, the failure to recognise the social nature of learning, and also viewing discourse as the prime collaborative form.

This section concludes by reviewing rather extensively a paper which is relatively closer to this thesis than any other publications. It is mentioned in the section that addresses the personalisation issue of publications although it also has some other shortcomings. Given the importance of personalisation in supporting LD students, it was considered to be more appropriate to include it here in this section.

There has been an increase in the use of modern technologies within teaching in general and specifically in the field of Higher Education, however Nganji et al., (2011) note that there is currently a problem for disabled students in Higher Education in that they often experience difficulty accessing assistive technologies in their learning environment.

Nganji et al., (2011) state that there are increasingly more learners with disabilities entering higher education in the UK. They point out that legally these learners have the right to "...be given equivalent learning experiences to their non-disabled peers through "reasonable adjustments" but because universities are struggling to match appropriate assistive technologies to disabled learners' needs a 'disability divide' has emerged, which lets down the most disadvantaged learners. In response, the authors suggest 'a disability ontology' that would provide a breakdown of the types of disabilities students present with, so that the institutions would be clearer about what their specific needs are. The aim of the authors is to apply their disability ontology within a diagnosis inference engine so that learners' needs will be matched up with learning solutions. One limitation of this ontological model is that it involves a learning environment with many learners, but one goal. It does not therefore allow for the uniqueness of every single learner. Learners with disabilities are often on a spectrum, so that their needs are never identical to one another (Nganji, Brayshaw & Tompsett, 2011).

This thesis defines the Semantic Web and the layers of the semantic web and describes how it will revolutionize the way people with disabilities access learning environments and states that e-learning personalization greatly benefits from this technology. The authors developed an ontology which could serve as a knowledge base for personalizing learning for disabled students. Their proposed ontology, Abilities and Disabilities Ontology for Online

Learning and Services (ADOOLES) is used, according to the paper, for personalization, but there is little evidence how this is materialised in terms of providing personalised services to users (Nganji, Brayshaw & Tompsett, 2011).

Apart from the personalization issue which will be looked at again, there are some other limitations to this study. The model proposed by the authors is a knowledge based system which requires a large amount of information to be stored prior to any computation-taking place. The problem with this is that, at the point when the LD student enters the learning environment, they may have to wait a long time for this information to be retrieved and allocated to their personalized learning plan. Students with disabilities often struggle with concentration issues and are therefore not very patient, (e.g. students with ADD/ADHD and Autism) – therefore their learning experience could be negative due to having to wait too long, losing interest and losing motivation. A system requiring long waiting periods has a flaw in it, when it is aimed at supporting LD learners. In addition to that it is almost impossible to design an ontological model in advance that has defined every possible disability or combination of them applicable to one individual. This is to say that, many LD students have complex disabilities, for example they may have ADD/ADHD and dyspraxia, or dyslexia and dyspraxia or a combination of dyslexia and mental health issues. Therefore, a LD learner using the proposed model will have addressed just one aspect or part of their needs and other needs will be overlooked.

Another concern about Nganji et al., (2011) study is that there is, arguably, an ethical issue. When they discuss how to assess the specific needs of LD students, one of their suggestions is to obtain information through the students' browsing behaviour. Every Web user, including the LD student, has a right to privacy when browsing online and the assumption that it is appropriate to watch when they are online is questionable. Their classification of autism is also disputable. Within ADOOLES autism is classified as a mental disability, which is not right. Indeed, on the website Autism.org it states that although learners with Autism face difficulties they are often, as in the case of learners with Asperger's Syndrome, '... of average or above average intelligence." Consequently, autistic learners should appear under the sub-class of Specific Learning Difficulties (SpLDs). Further evidence for suggesting that Autism is mis-classified is that Asperger's Syndrome appears under the SpLDs sub-class, and "Asperger syndrome is a form of autism." www.autism.org.uk.

The author's proposed model also contains a major shortcoming in that it describes disabled groups of people in a somewhat stereotypical way. It offers learning plans based on generalised disabilities, however most disabilities, such as autism, dyslexia, dyspraxia, etc. are spectrums, which means that although there are some general commonalities in terms of processing difficulties, each learner has a unique profile, and therefore a unique and specific set of needs. This would therefore minimise the level of personalisation of the model. This thesis, however, avoids a simplistic and reductive approach to LD students' learning opportunities and offers a learning plan modeled on a break-down of their specific needs, rather than offering a generic plan for them simply because they have been given a disability label.

3.5 Application of Semantic Web in Learning Environments

Bittercourt et al., suggest that there is a need "... to provide more adaptability, robustness and richer learning environments." (Bittencourt et al., 2008) (Bittencourt et al., 2009). They reference recent innovations in the design of Artificial Intelligence in EDucation (AIED) through the incorporation of semantic web resources. They point out that this is difficult for software engineers, but believe that using a computational model for the development of Semantic Web-Based Educational Systems (SWBES) will make it easier for both authors and also developers.

As web-based systems have become increasingly more complicated, challenge have arisen vis a vis AI and software engineering. Therefore, Bittercourt et al., have conducted research and drawn conclusions regarding the problems involved in Adaptive Web-Based Educational Systems (AWBES). The goal of AWBES is to improve the quality of online interactions and activities for learners. The presentation adaption, as described by Bittercourt et al, states that a different user interface is used for each student; however this adaption looks more widely than at what one individual student has previously done during their last interaction online. It goes further, by drawing from interactions with other users (Bittencourt et al., 2009).

The proposal of this thesis, however, differs from this, as generalisations are not made based on disability "categories", nor are parallels drawn from the experiences of other LD students' experiences online. The author of this thesis stresses the fact that every single online interaction is a moment in time, and the results are deleted immediately after the student logs off. This is important as it recognises that the mood, concentration level, motivation level and wellbeing is a changing status – it is not constant. Therefore, each time the LD student logs on, they experience a specific moment in time, which is personalised. It is not in any way linked to the learning profile of any other student.

When comparing the author's ontology to the ontology of Bittencourt et al (2009), discussed in Section 3.5, there is a significant difference. The researcher does not use Artificial Intelligence in Education (AIED), because they are not working in the Artificial Intelligence field. Instead the author uses Software Engineering (SE) mechanisms to create and implement the proposed reference computation model. In contrast, Bittercourt et al state that they specifically use AIED via the use of semantic web resources The new generation of AIED system have two types in this generation IN Bittencourt et al (2009):

- LMS
- AIES system

our research is likely to belong to the second one with a huge different as it is not artificial technique and in the background of our proposal is a SE computational model but the outcome is the same! the outcome of our work should be combination of so called semantic web-based education system and its small sections which can run as Apps.

3.6 Forethought

After examining the literature, the author was very concerned that research does not go far enough to address all the important issues in modern education; particularly (a)-(d) from Chapter 1. One of the most important aspects of a personalised learning environment is its impact on the learning curve of each individual student, regardless of their background, disabilities, culture, religion, interests, etc.

Furthermore, no similar solutions were found in academic studies, which use OWL/SWRL enabled ontologies for managing the semantics of the learning environment in any circumstances i.e. with and without thinking about LDs. This pathway of the research has no particular counterparts in the reviewed literature and therefore brings a complete innovation on how to build the semantics of learning spaces which suit students with LDs, and satisfies students' expectations and learning outcomes.

In other words, the exploitations of OWL and SWRL brought new software engineering solutions in terms of creating semantics and manipulating them for the purpose of building a software application based upon OWL repositories.

Chapter 4

The Research Proposal Model

After the background elucidation and related work explication in the literature in chapter 2 and 3, an elaboration of the research proposal to address the shortcomings of existing solutions is provided in this chapter. For clarification, outline of the shortcomings is reiterated before a full account of the proposed model is explained.

4.1 Shortcomings of the existing solutions

The chief problem of the existing solutions that try to address the needs of pupils with learning difficulties is that they are fragmented.

Solutions are not comprehensive enough to be applicable to different environments with different settings (Mizoguchi & Bourdeau, 2000) (Alberta Learning, 2002) (Alberta Learning, 2003-2004) (Bourdeau et al., 2007) (Price, 2009) (Popescu, 2009) and (Nganji, Brayshaw & Tompsett, 2011) (Nganji & Brayshaw, 2013) (Nganji, Brayshaw & Tompsett, 2013) (Nganji & Brayshaw, 2014).

They are tailored to some specific disability or to some learning process explicit for some individuals.

A model solution that is not generic enough to accommodate different types of disability with different types of learning needs or desire is at best a software application for some specific purpose.

In environments whereby the organisers' prime concern is to facilitate and improve learning experience of individuals with learning difficulties, at any given time the information about the availability of different teaching elements pertinent to the learning experience is essential. One of the shortcomings of the current solutions is

a) the problem of deciding what teaching materials are suitable, available and ready for helping out pupil or pupils with some LDs in a particular class.

This problem, a) above, is exacerbated when the learning experience is taking place in a VLE which should enable LD pupils to contribute to any discussions and interact with the class through the VLE. In such environments it is essential to know precisely what technologies should be present. Some systems rely on ontological engineering to overcome common Artificial Intelligence in Education (AIED) problems (Mizoguchi & Bourdeau, 2000).

Such systems use Adaptive Web-Based Educational Systems (AWEBS) and rely on an expert system which stores an individual?s personal information and reuses it. The e-learning experience of an individual is therefore generalised. This is an issue, because LD learners are all unique, and so sharing other learners? personal information and their learning experience and outcomes is not appropriate. Although it might be argued that the reuse of aggregated information is not breaching or penetrating any ethical standards, its relevance to an individual LD learner is probabilistic and therefore a definite decision cannot be made. Therefore,

b) determining what technologies should be present in a concerned VLE to collectively facilitate LD pupils learning experience is the next problem of current systems.

It is equally important to note that learning environments that do not support accommodation of social media tools and communication facilities within, is also part of the author's concern for technology support stated in b) above.

A system incorporating these facilities to balance the differences in learning curves found in LD learners would help them on their journey through the reading process. Existing systems have a lack of automated reasoning, and this leads to a problem of inclusion for LD students in mainstream classrooms. The inclusion issue revolves around the fact that traditional methods heavily rely on the syntactical and semantic nature of the spoken language, which involves the demands stemming from language scripts and cultures. However, some pupils perceive the world differently, and their concentration levels and capacity to memorise is often adversely impacted by their processing difficulties. In turn this means it can be harder for them to learn to read, as they often need to decode words one by one. The sheer effort and time this takes means that they are so busy concentrating on breaking down the individual sounds and as a result they lose completely the meaning of what they are reading. Therefore, a learning process is needed which contains a unique set of instructions on how to carry out teaching activities for each student in the classroom, so that learning is personalized. The researcher's model addresses this issue and uses a learning process for each pupil which is completely personalized, introducing a set of distinctive instructions on how to perform teaching activities in the classroom which are suitable for all pupils. Pupil's personalized profile, in terms of age, background, interests, learning abilities and goals will dictate which technology and individualized learning plan will be generated. Such a system would allow teaching activities to be sourced, which are tailored for the individual with LDs. In addition,

c) lack of automated support to resource teaching activities is another issue of concern.

Therefore, shortcomings of the existing solutions for helping out pupils with some LDs in a particular class or VLE are:

a) deciding what teaching materials are suitable, available and ready for all pupils

b) determining what technologies should be present in the concerned environment to facilitate learning experience

c) lack of automated support to resource teaching activities

4.2 Proposed solution

This section outlines the research proposal also stated briefly in chapter 1 section 1.3 and 1.4. In the subsequent sub-sections further detailed explanation is provided.

Any system that addresses problems a) to c) above should be able to use a variety of software tools, supporting a range of VLEs and to ensure that the settings in classrooms accommodate the special needs of LD students by personalising the space. This entails taking into account issues such as the diverse range of impairments and needs that exist among learners, personal preferences, and a tailored learning space and not a generic plan. In this way, LD students will be offered a range and choice of options that suit them.

The improved system will also need to have technology affinity and compatibility of any solution with assistive technologies to facilitate the various impairments, and generate an individual, tailored learning plan which will best support an LD student?s diverse needs.

As a prerequisite for a) - c) above, investigation into the characteristics, functionalities and contents of LEs which can lead towards an ad-hoc configuration of their instances, LeS, is the initial purpose of the research. Once this is established, only some of the key elements of the LeS that can form a computational model as a proof of concept that is highly personalised to learners? needs will be identified. Personalisation of such spaces for LD students will take into account aspects (a) - (d) mentioned in section 1.3 Chapter 1.

These learning aspects inform and define a conceptual model of an LE which can be accurately configured into a specific set of LeS. The innovations needed to find an appropriate solution including the development of improved computational models with the ability to configure LeS, and cope with their main artefacts. With this in mind, this research aims to define a specific reference computational model, which incorporates the ideas above and secures the implementation of a LeS.

4.3 The Proposed Reference Model for Configuring LeS

The author's reference model given in Figure 4.1 illustrates the role and the content of the computational model named Managing Semantics of Learning Spaces (ManSemLeS), which helps ad-hoc configuration of a LeS.

The ManSemLeS, is divided into three distinctive parts: the GUI-APPLICATION components which define interfaces that may exist when creating LeS, the MODEL components, which store domain, learners and instructional models needed for the creation of LeS and MANAGEMENT components which manage the semantic stored in various model components in order to carry out the configuration of a LeS.

GUI-APPLICATION is essential for communicating and formulating demands upon the ManSemLeS and for displaying the computational output from the ManSemLeS. For example, the computational model must describe which ?kind of content? will be computed through ManSemLeS or which kind of output may occur, as a result of computations.

It is important to note that the reference model focuses on its layered computational core (LeSMM), which shows the way of defining, storing, and manipulating the semantics of LEs when configuring a particular LeS. However, without adequate user interfaces and software applications, which host them, the researcher will not be able to detect demands of users who are willing to participate in a particular instance of LE and become a part of an LeS.

Therefore, no LeS can be configured if users (learners) are not allowed to clearly express their needs and expectations. As previously indicated, it is very likely that the set of LeS, at the bottom of the proposed referenced model, is a cyber/physical space, which it should be to possible to configure through the computational core. This means that all possible situations should be allowed for: from creating a physical, and traditional classroom to purely virtual LeS which have been configured strictly according to the user's needs and expectations (learner's and instructor's demands).

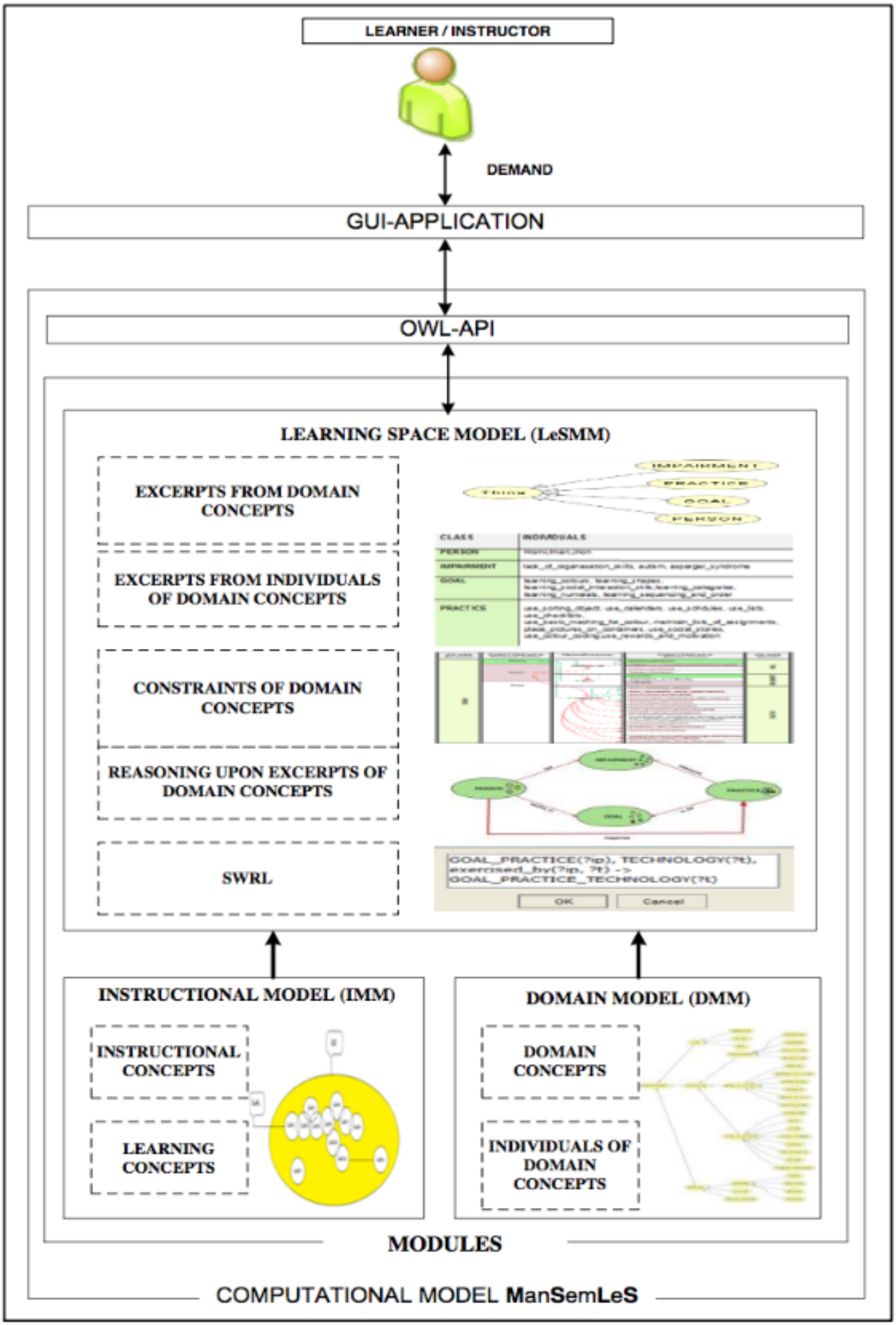


Fig. 4.1 The Reference Model for Creating LeS

Figure 4.1 distinguishes between two different types of ManSemLeS users: Learners and Instructors. Learner enter LE because they have their own goals and demands in terms of

(a) willingness and need to participate in a particular learning session

(b) need to express their perosnalised profile as learners (academic and personal profile)

(c) need to articulate any DiffInL they may have.

On the other hand, instructor enter LEs because there is a request for them to participate in a particular session which will then include

(1) instructional design of a learning process, including learning sources/materials,

(2) assessing a learner's performance and learning outcomes.

In the next section the Domain Model Module which forms the foundation for the Learning Space Model is explained in detail.

4.3.1 The Domain Model Module (DMM)

The Domain Model Module (DMM) Figure 4.2 contains ontological concepts and their hierarchies which belong to any LE (Almami & Juric, 2011b).

These concepts define the basic semantics of any LE and should include a personal learner's profiling with emphasis on DifInL and their impact on learning processes. Therefore the DMM should store concepts and their relationships, which describe any possible situation that may be encountered in the LE. The semantics of DifInL and its role in creating an LeS, must be understood and interpreted. It is expected that DifInL be modelled from various perspectives: the individual profile of the learner, types of differences he/she may exhibit in learning, goals of a learning session and a sequence of activities that must be performed in order to claim that this is an effective LeS for a particular learner.

It is important to note that the ontological model from the DMM is not formal domain ontology. In the literature when the term "domain ontology" is used a formal definition of all concepts and relationships between them is meant. Whereby application-specific ontology is referenced as domain independent model that in collaboration with domain model serves a particular problem. In this research the domain ontology is somewhere in between. It is not a formal ontology and is not application-specific ontology. It is generic enough to address learning needs of students with learning difficulties, whilst not comprehensive in terms of its axioms to represent the entire LE concepts.

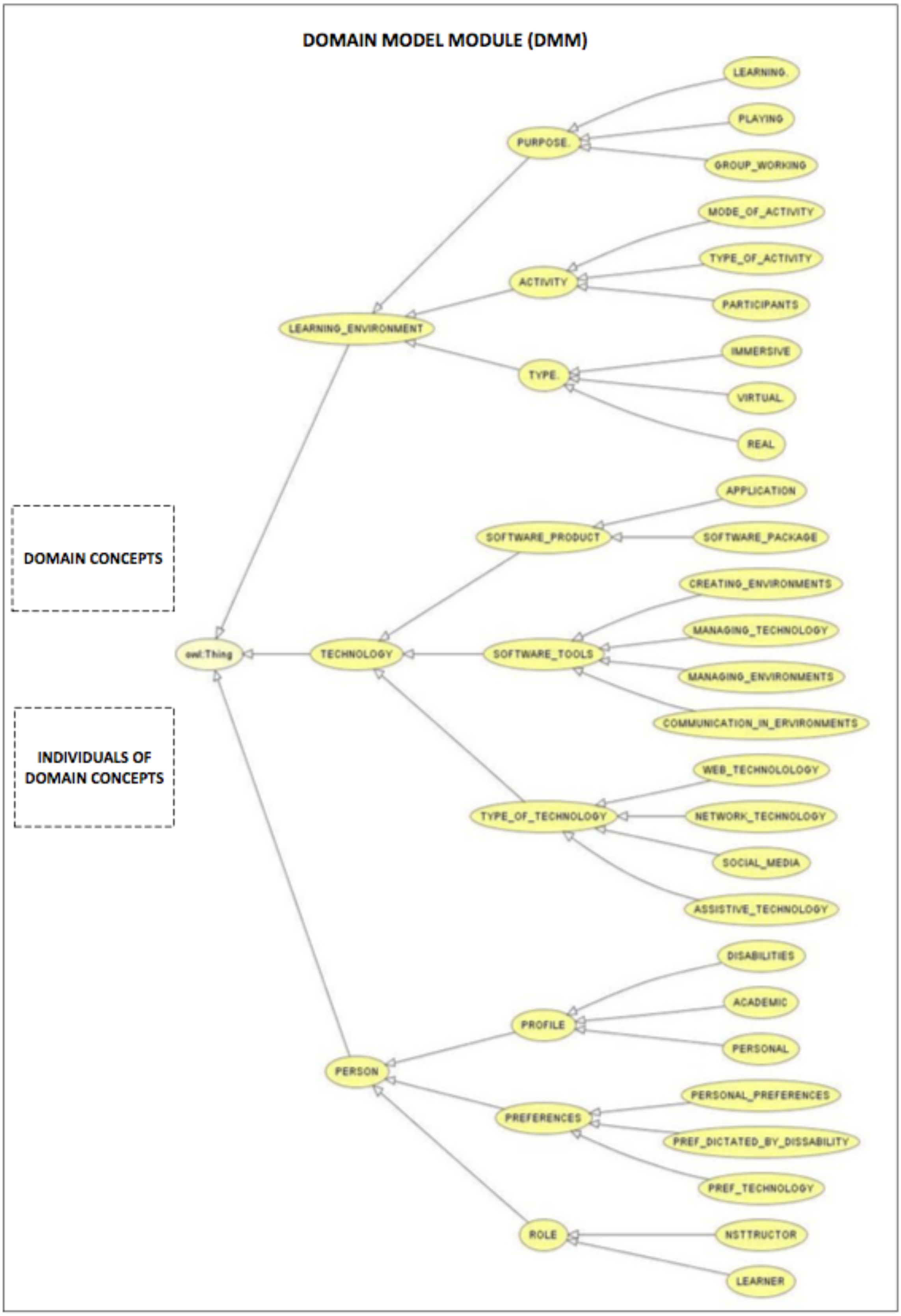


Fig. 4.2 The Domain Model Module (DMM)

On this basis the domain model this research represents is a knowledge base, KB that is comprised of both T-Box T, set of axioms about the concepts and relationships between them, and A-Box A, set of individuals that are member of some concept. This is to say that the $KB =< T,A >$ If the LE domain is represented as $LE\Delta$ then it can be said that all concepts $C \subseteq LE\Delta$, that are the domain individuals $i \in LE\Delta$, and that all relationships $r \subseteq LE\Delta \times LE\Delta$.This refers to a binary relationship r that a class per and class i of C have with each other:

$$per \longmapsto i : r \subseteq LE\Delta$$

For example PERSON is a concept within C, that is PERSON $\in C$. An individual i of PERSON is denoted by PERSON (i). And where the individual is shown as a variable x it is denoted as PERSON (x). In the $LE\Delta$ every individual of PERSON has some type of impairments. That is to say that

$$\forall per(\text{PERSON}(per) \to \exists i(\text{IMPAIRMENT}(i) \wedge \text{ has } i))$$

This is shown in Figure 4.3 In Description Logic terminology, that is to say that for all per

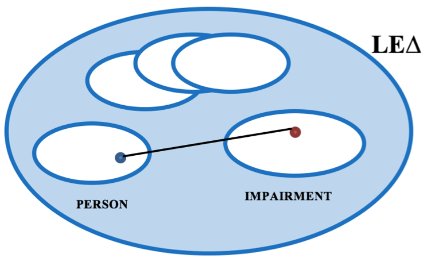


Fig. 4.3 Structure of $LE\Delta$

that is a PERSON, definitely there must exist some IMPAIRMENT i and that the individual per has i. The expression is not of course a universal one that applies to every single human being. The expression is only true within the $LE\Delta : T \subseteq LE\Delta$. In $LE\Delta$ the researcher is only concerned with concepts which are sufficient for describing basic semantics of the environment. The representation of $LE\Delta$ can be strengthened through various other OWL concepts by introducing sub-hierarchies of existing classes, and relationships. For example as shown in Figure 4.3

$$\text{PERSONAL\_PREFERENCES} \subseteq \text{PREFERENCES} \subseteq \text{PERSON}$$

In OWL terminology it reads as PERSON subsumes PREFERENCES which in turn subsumes PERSONAL_PREFERENCES.

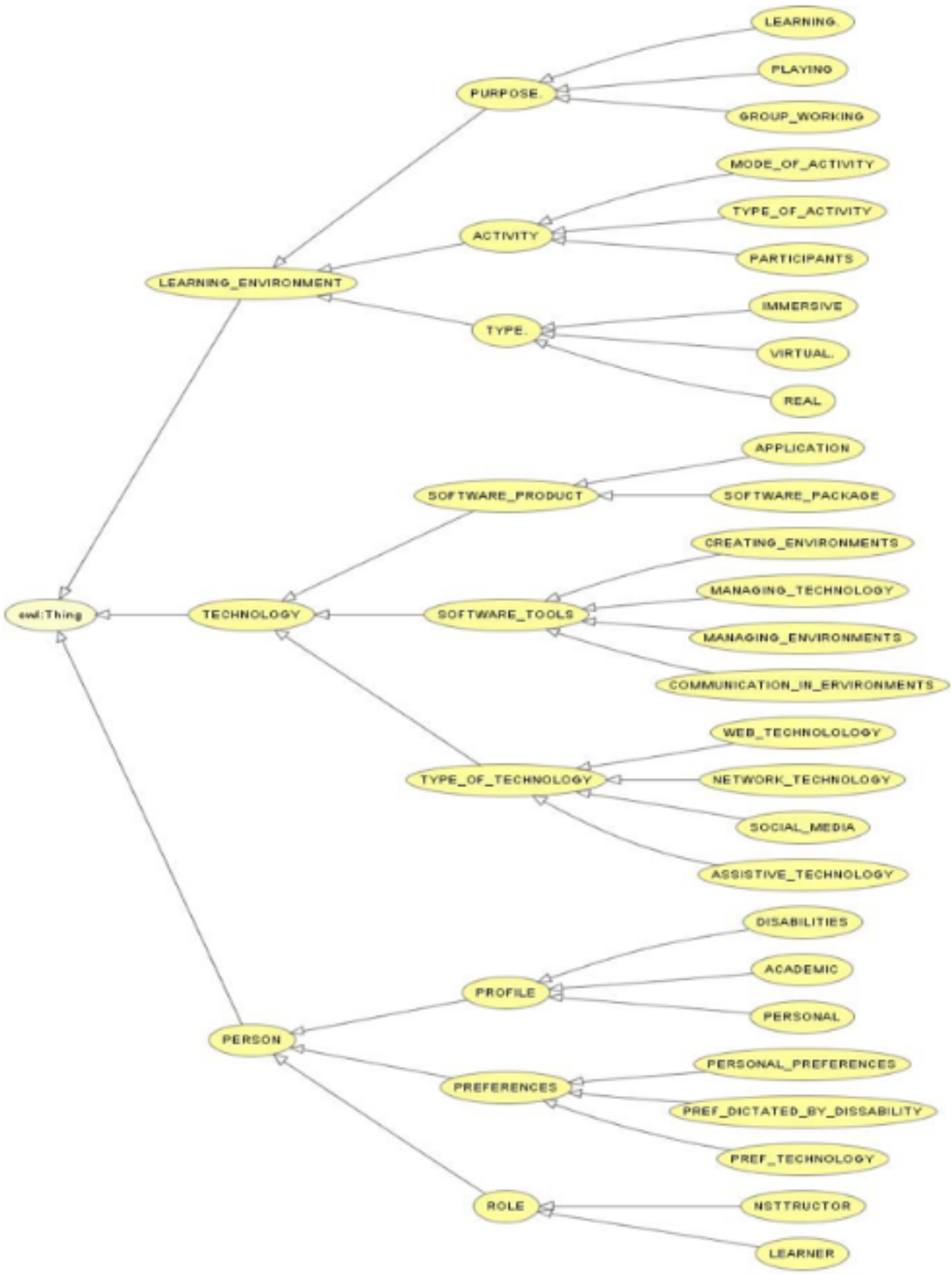


Fig. 4.4 Full hierarchy of ontological classes from DMM

Figure 4.4 above shows a basic ontological model, which stores semantics of LEs. The researcher's choice of basic ontological classes, which is self-explanatory, is debatable, but it follows the earlier experience of modeling the semantics of pervasive environments, (Almami et al., 2012) (Almami et al., 2013) (Almami, Juric & Ahmed, 2014) (Almami & Juric, 2011b) (Almami, Juric & Zaki Ahme d, 2015) where people, devices, technology and services delivered in them are interwoven. It is obvious that there will be semantic overlapping between sub-hierarchies of LEARNING ENVIRONMEMT, PERSON and TECHNOLOGY classes, i.e. when describing the $LE\Delta$ it must be taken into account that its semantics can be juxtaposed to:

i) learners/instructors profiles and their expectations from LE and

ii) technologies which are an important part of any LE.

Semantic overlapping secures inferences, i.e. it can trigger reasoning, which will determine exactly which characteristics a configured LeS should have if it is expected that learners and instructors will participate in it.

It is important to note that it was not possible to find any suitable domain ontologies, which could help to describe the semantics of LE and LeS. In other words, it was not plausible to look at any existing attempts to formulate the formal semantics of LE with formal languages like OWL. However, this is not a particular concern of the researchers for two reasons:

(i) Domain specific and formal ontologies are difficult (if not impossible) to use in modern software applications, which require certain performance characteristics in terms of their ad-hoc creation, responsiveness to the environments where they reside (LE and LeS) and their implementation on wireless/mobile devices.

(ii) This research is not in the field of knowledgebase systems where the researcher should be gearing her modelling towards creating her own domain specific ontology for any LE! We are partly knowledge based;

however, the results are not stored or re-used. It is therefore new and different from expert systems which already exist. The intention is not to build an expert system, nor is to create any persistence, which grows proportionally to the level of inference mechanism defined upon the researcher?s designed ontology when configuring LeSs.

In contrast, the researcher?s domain ontology is broad and only the required classes are extracted from this, with (i) only a fraction of individuals asserted and (ii) all results of inference are deleted, after running the application created upon the ontology, i.e. after a particular LeS is configured.

4.3.1.1 The Ontological Model

The ontology, shown in Figure 4.4, is an excerpt from a full scale set of ontological concepts which have been elaborated in (Appendix A),(Almami & Juric, 2011b) and (Almami & Juric, 2011a). Each of the leaves of the ontological structure from Figure 4.4 has been extended into sub-hierarchies, according to various domains of interests and the purpose of the ontologies when resolving problems in learning environments. The ontology has been created for the purpose of satisfying the objectives of this research (Chapter 1, section 1.4) and therefore the choice of axioms and inference which accompanies the reference model is dictated by the three main conditions, when determining how to convert the semantics of LE into OWL concepts:

a) There has to be sufficient set of classes and their hierarchies to describe the basic semantics of a LE to achieve $LE\Delta$,

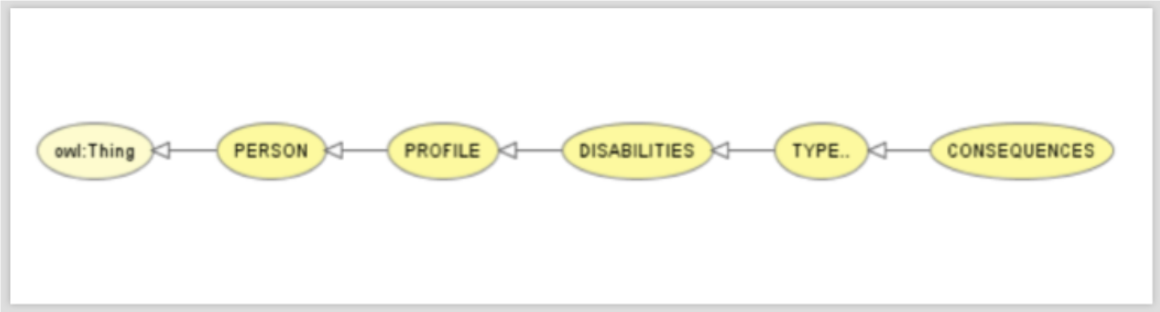
b) It should be possible to extend the model from a) and assert/infer more concepts (sub-hierarchies, properties and individuals) in order to strengthen the semantics of the ontology according to ‘demands’ imposed by learners and instructors,

c) There should be a way to secure a reasoning mechanism upon the ontological concepts from b) in order to create inference and configure LeS.

It is important to note that the model shown in Figure 4.4 has been re-used in several experiments for decision making in learning environments. Therefore, the main ontological concepts and their hierarchies should contain overlapping semantics in order to enable the reasoning with OWL and SWRL. It is possible to describe the semantics of any learning environments if one uses sub-hierarchies of PERSON, LEARNING_ENVIRONMENTS and TECHNOLOGY and enrich them with constraints. However, the exact choice of sub-hierarchies, their further extensions and choice of their classes from Figure 4.4, which will be involved in reasoning, depends on the need to perform decision making in order to create a particular learning environment.

In other words, the extensions of ontological leaves from Figure 4.4 becomes essential. For exploiting the ontology in a particular decision making process and within a particular domain of interest. For example, in (Almami et al., 2012) it became necessary to extend horizontal hierarchies of some of the existing classes of Figure 4.4 as shown in Figure 4.5a - Figure 4.5c.

The reason why only DISABILITIES, LEARNING, ASSISTIVE_TECHNOLOGIES and TYPE_OF_ACTIVITY classes were chosen was due to the fact that they carry enough semantics to address the given scenario (Almami et al., 2012). The DISABILITY class from



(a) Extension of the DISABILITY class

(b) Extension of the TYPE_OF_ACTIVITY class

(c) Extension of the LEARNING class

Fig. 4.5 Extensions of classes

figure 4.5a has a set of subclasses, but TYPE and its subclass CONSEQUENCES store the exact information on any possible manifestation of Autism Spectrum Disorder (ASD) which might be found in pupils, which are relevant to the teaching and learning process and tasks performed in the classrooms.

The TYPE_OF_ACTIVITY class from Figure 4.5b has a set of subclasses, but the LEARNING_IN_THE_CLASS and CLASROOM_TASKS store the exact information on all possible activities that may run in the class for the purpose of ‘learning’, i.e. t. the instructor needs to define which particular academic task he/she would like to perform in the classroom as a part of learning activities.

The LEARNING class from Figure 4.5c has a set of subclasses, but INTRUCTIONS and its subclass PROPOSED PRACTICES store the exact information on how to perform the academic task in terms of having a set of instructions which would be proposed as practices in order to secure learning outcomes. The instructor will adopt instructions, advice, recommendations and suggestions in the classroom as ‘proposed practices’ in order to perform a desired academic task.

While the intension was to enrich the T-Box T as opposed to the A-Box A , it became evident that further horizontal extension of ASSISTIVE_TECHNOLOGIES would unnecessarily complicate the ontological model. Therefore, all possible assistive technologies were added to the A-Box as the class individuals.

In another experiment in a particular situation in LE, the researcher wanted to see if the materials were ready for a particular class and if they would serve students with LDif. In OWL/SWRL terms the aim was to capture the semantics of such LE in ontological classes from Figure 2 and reason upon it in order to answer a particular competency question:

"What materials, in terms of their content and format, are ready for accommodating students with dyslexia and Attention Deficit Hyperactivity Disorder (ADHD), for the purpose of running a session on Social Intensive Systems, taking into account that these students have particular interests in Social Network Privacy and Security (SNPS)"?

The premises of the above competency question in Description Logic format would be:

$$\text{PERSON} \sqcap (\exists \text{ has Dyslexia.DISABILITIES}) \sqcap (\exists \text{has ADHD.DISABILITIES}) \sqcap (\exists \text{ interested In SNPS.PREFERENCES})$$

To answer the question, the following steps were taken:

- firstly, to extract which classes from the ontology will be sufficient for answering the question and are involved in reasoning;
- secondly, to define constraints, value and existential constraints

  $$(\forall \textit{ and } \exists)$$

  on the selected classes in order to strengthen the semantics of the ontology and prepare it for reasoning;
- thirdly, to run SWRL rules upon these selected classes to find the answer to the competency question.

The selection of classes which is solely based on the competency question above is shown in Figures 4.6.

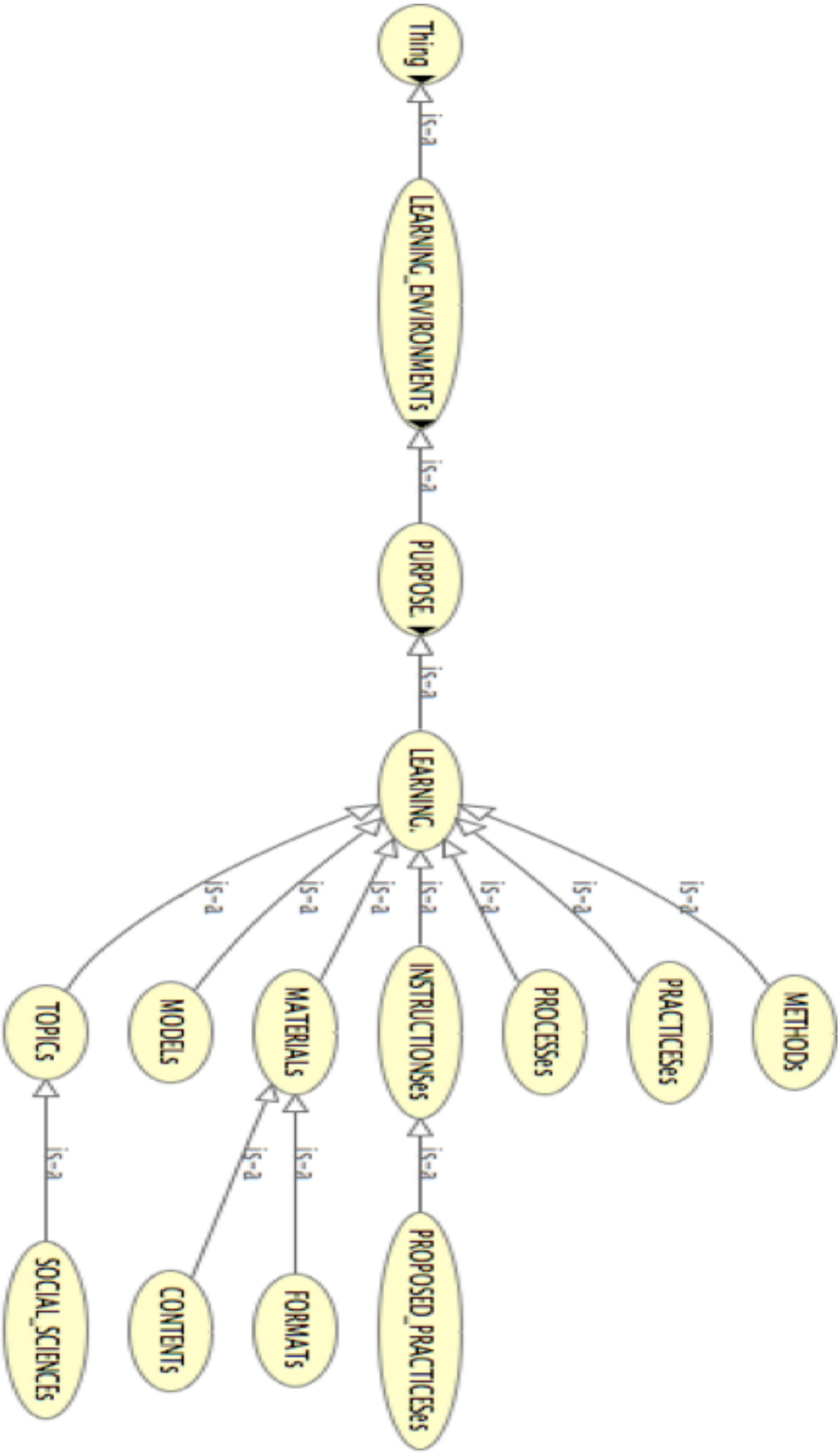


Fig. 4.6 Extension of the LEARNING Class

The possibility of horizontal extension of DMM according to specific needs has been shown here. As far as OWL and SWRL are concerned each instance of an ontological model answers a specific competency question through inference. Thus, the issue of competency questions is probably the main rationale behind deciding exactly which OWL concepts are going to represent which part of the semantics of LE. It has been decided that the term DISABILITY should stay within the ontology as a vehicle which can then allow situations to be modelled when:

a) ‘disability’ causes LDif, or

b) ‘disability’ can be connected to DiffInL, or

c) ‘disability’ is NOT connected to DiffInL, LDif etc.

This will help to mark which ontological concepts will carry the semantics of disabilities in general, and which will be related to LDif and/or DiffInL by either extending classes from Figure 4.4 through their sub-hierarchies or imposing constraints on the ontology.

The rationale behind modeling the PERSON sub-hierarchy is dictated by the purpose of the ontology: it should be possible to match individuals from the sub-hierarchy of the DISABILITIES subclass with any other individuals in sub-hierarchies from the learning environment and services delivered within them, which are available in Figure 4.4.

Therefore whichever set of subclasses are created when describing disabilities (i.e. LD/LDif/DiffInL) in the ontology, it must be borne in mind that they have to be addressed in LEs through various activities/practices, which may have a form of service delivered within a personalized LeS.

In other words a ‘space’ must be found for dealing with DiffInL and instructional design, and the author must also must be able to manipulate the semantics of the ontology in order to secure a)-c) above.

4.3.1.2 Extending the DMM Classes

In order to strengthen the semantics of the DMM ontology for the purpose of addressing the ‘demand’ when configuring a LeS, it is sometimes essential to extend leaves of classes of the ontology in Figure 4.4 with sub-hierarchies. In this subsection one example of creating a deep sub-hierarchy for the DISABILITY class, is given in Figure 4.7.

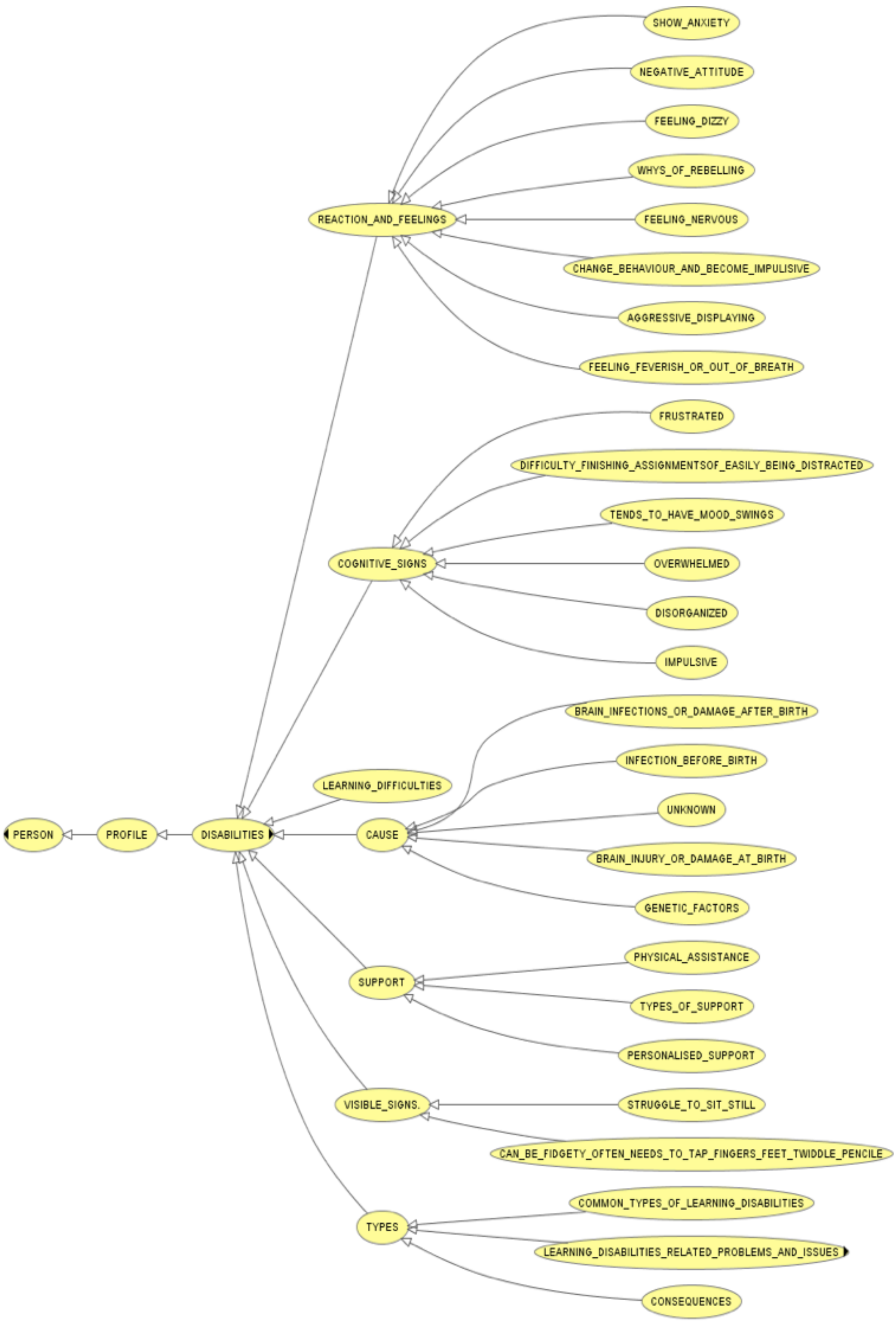


Fig. 4.7 Horizontal Hierarchies for Disability Subclass

The rationale behind modelling the PERSON sub-hierarchy is dictated by the purpose of the ontology: it should be possible to match individuals from the sub-hierarchy of the DISABILITIES subclass with any other individuals in sub-hierarchies from the Learning Environment and services delivered within them.

Therefore, whichever set of subclasses are created when describing disabilities in the ontology, it should be borne in mind that they have to be addressed in LE? through various activities/practices, which may have a form of a service delivered within a personalised LeS. In other words, the ontology should contain the semantics which will enable all three objectives of this research to be delivered.

A 'space' must be found for dealing with DiffInL and instructional design, we also must be able to manipulate the semantics of the ontology in order to secure a computational model from (ii) and (iii) in the Introduction.

There are seven main subclasses of the DISABILITY class as shown in Figure 4.7 above:

TYPE $\subseteq$ DISABILITY, CAUSE $\subseteq$ DISABILITY, SUPPORT $\subseteq$ DISABILITY, VISIBLE SIGNS $\subseteq$ DISABILITY, COGNITIVE SIGNS $\subseteq$ DISABILITY, REACTION_AND_FEELING $\subseteq$ DISABILITY and LEARNING DIFFICULTIES $\subseteq$ DISABILITY.

These subclasses are disjoint classes: DisjointClasses (TYPE, CAUSE, SUPPORT, VISIBLE_ SIGNS, COGNITIVE_ SIGNS, REACTION _AND_ FEELING, LEARNING_ DIFFICULTIES)

They are chosen for the purpose of having a provision within the ontology where we can store the semantics of DiffInL.

The term LEARNING_ DIFFICULTIES was left as a subclass of the DISABILITY class within the ontology for one important reason: it will enable the author to decide, when creating a particular LeS, whether DiffInL will be modeled as an individual of the LEARNING_ DIFFICULTIES class, a constraint between the PERSON and LEARNING_ DIFFICULTIES classes or a simple subclass of the LEARNING_ DIFFICULTIES class.

This decision can be made only after a particular 'demand' imposed by learners and instructors is analysed. Furthermore, we might need all these subclasses of the DISABILITY class for ontological matching, i.e. the inference mechanism, which ultimately configures a LeS. The flexibility of OWL allows for a choice of classes from Figure 4.4 to be involved in the reasoning.

When describing the semantics of LDif/DiffInL within the DMM ontology, more emphasis might be put on constraints instead of sub-hierarchies. The same applies to any of the ontological design decisions: the exact modeling decision on 'which OWL concept will model what' is always specific to a particular configuration of LeS ('demand') (Almami et al., 2012). The deepest hierarchies in the DMM ontology have been created for types of disabilities and their support. Relatively shallow hierarchies for CAUSES needed necessary.

In terms of modeling cognitive signs, these can be easily categorised as individuals in OWL (from the available literature) and therefore a deeper hierarchy for them was not felt necessary.

The richest part of the DISABILITY sub-hierarchy is a sub-hierarchy of the class COMMON_ TYPE_ OF_ LEARNING_ DISABILITIES. COMMON_ TYPE_ OF_ LEARNING_ DISABILITIES $\subseteq$ TYPE $\subseteq$ DISABILITY

It should be noted, as it will be seen shortly, that it is always possible to balance these deep horizontal hierarchical subclasses against object properties that were referred to earlier as binary relationship between two individuals in section 4.3.1, which can be defined on the ontological classes and their sub-hierarchies.

4.3.2 The Learning Space Model Module (LeSMM)

The Learning Space Model Module (LeSMM) is derived from the DMM, which is created as a result of a particular 'demand' upon LE, issued by a learner. This means that we extract from the ontological model stored in the DMM only class hierarchies, T-Box T, and their possible individuals, A-Box A, relevant to the learner's demand, and infer sub-classes if required by the 'demand'.

The ontological model in LeSMM becomes learner specific and contains only the semantics which is relevant in a particular configuration of a LeS. However, it is not enough just to extract relevant concepts from the DMM; constraints need to be added, or any other means of improving the semantics of the LeSMM as a prerequisite for defining instructional and learning concepts, as part of the configuration of a LeS.

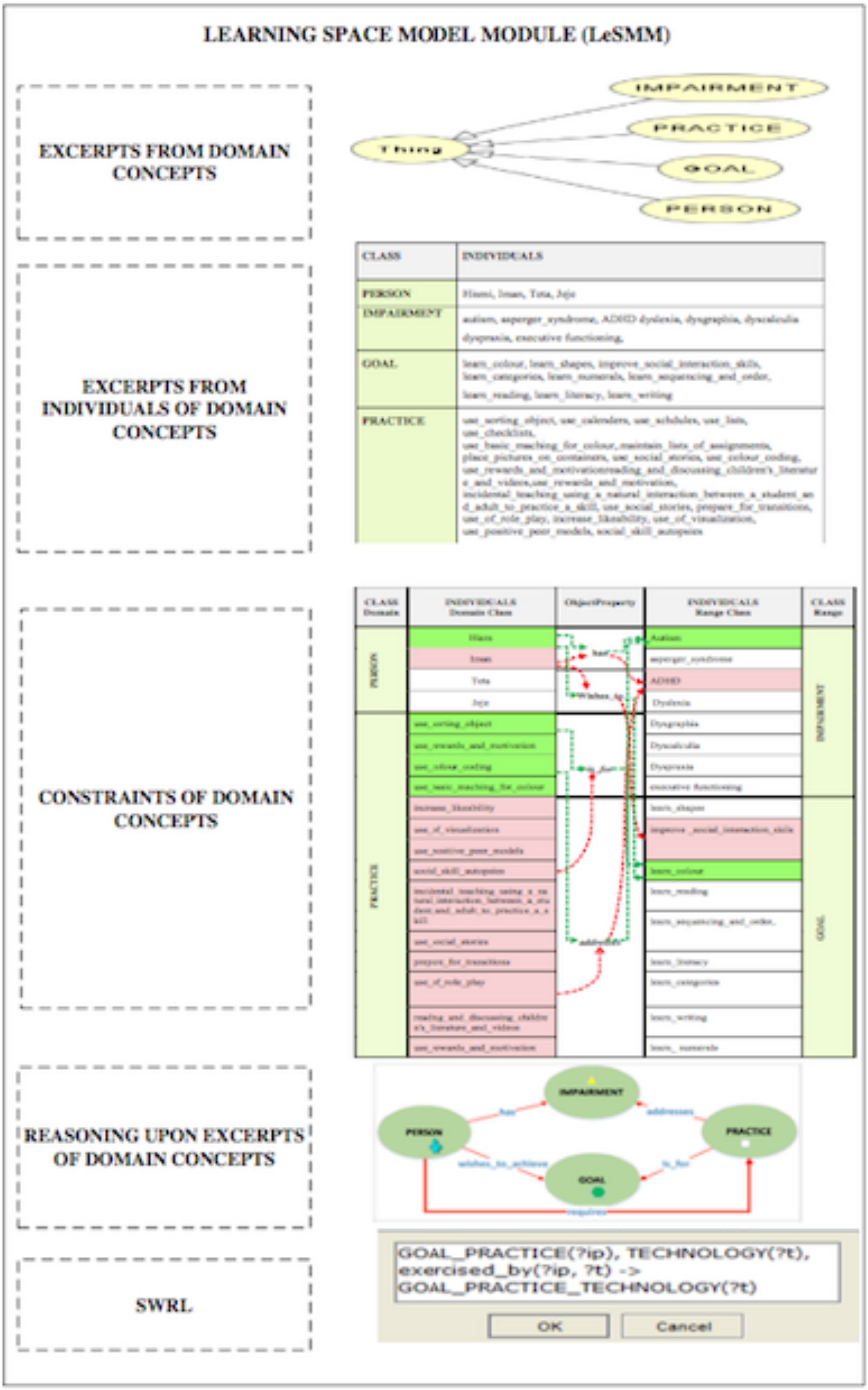


Fig. 4.8 Learning Space Model Module (LeSMM)

4.3.3 The Instructional Model Module (IMM)

The Instructional Model Module (IMM)uses the ontological model from LeSMM and runs reasoning rules upon LeSMM concepts in order to specify exactly: which instructions are needed for creating LeS, what are the exact learning/teaching activity sequences for that particular LeS, where the learning sources and materials are, what their content and format is and how they can be supported.

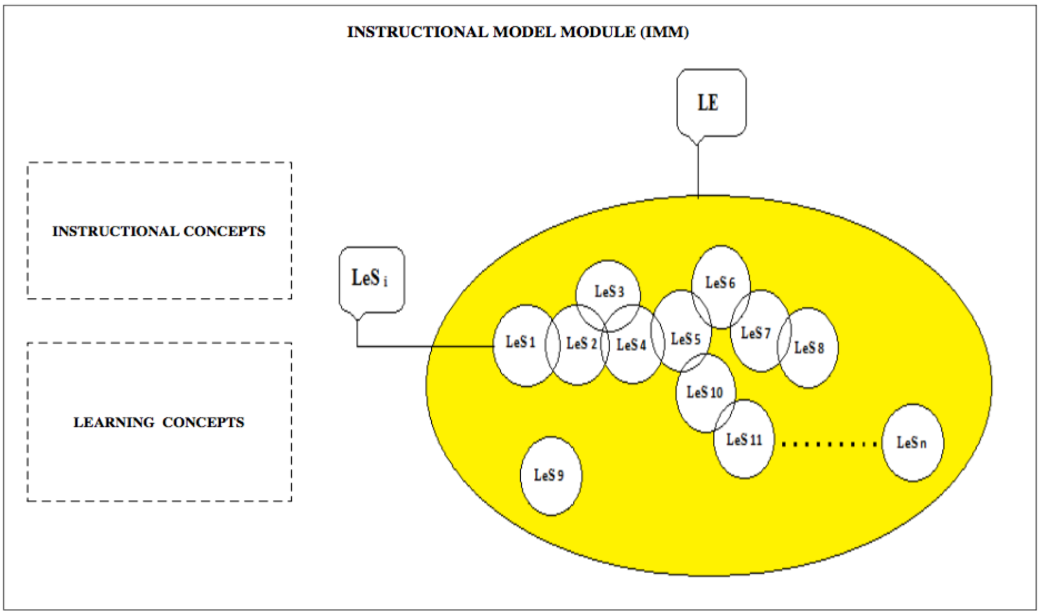


Fig. 4.9 The Instructional Model Module (IMM)

All three modules DMM, LeSMM, and IMM are mostly focused on repositories created within them, which are OWL ontologies. Therefore the functionality of the ManSemLeS should have the power of managing repositories and reasoning according to their purpose. Semantics of LE are managed at the generic level of DMM repositories, semantics are managed by creating repositories and constraints within the LeSMM through assertion and inference and finally, the process of teaching and learning is managed by generating instructional learning design in IMM as the results of inferences, which in turn configures a particular LeS.

4.3.4 Illustrations of LeSMM and IMM

The LeSMM module is responsible for interpreting the semantics of the 'demand' and extract relevant classes from the DMM ontological model and enrich them with additional sub-hierarchies, properties and individuals, which may be inferred or asserted. The IMM module will take the semantically rich ontology prepared by the LeSMM module and perform reasoning. It is difficult to illustrate these two tasks without being 'demand' and learner specific. The only possibility in this research is to illustrate types of demand, which may be issued, and which will then gear the configuration of a LeS. There may be a number of 'demands', which include the following:

- *Which measures need to be taken to address the problem of avoiding "eye contact" when teaching autistic students?*
- *What needs to be done to ensure that ADHD students are following instructions in a particular classroom?"*
- *As an instructor in a higher education institute, are materials ready in terms of their content formats and availability on hand-held devices, for a debate on Social Networking in Healthcare, and scheduled for all students regardless of their DiffInL such as Asperger, dyslexia, or visual impairments?*
- *What would be the exact set of instructions (including choices of technologies) to be given to children who are learning 'reading' in a mixed class of pupils with different mother tongues, DiffInL and different exposure to spelling?*
- *How can a correct selection of all possible hardware be made, (e.g. devices) and software solutions, which assist in a LE, which make provision for a clearly declared DiffInL?*
- *Some of students for a class at 3 PM are autistic – are the environments ready to guarantee their participation?*

Each of these 'demands', whether taken in groups or individually, carries semantics which help us to choose excerpts of ontological classes from the DMM ontology, assert either individuals and properties upon them in LeSMM and then infer whatever is needed to answer the 'demand' through the IMM.

For a full illustration of examples, how different demands create different ontological models based on Figure 4.4, and how OWL concepts are asserted and inferred in that model for preparing it for reasoning, please refer to to (Almami & Juric, 2011a) (Almami & Juric, 2011b) (Almarri & Juric, 2013) (Almarri et al., 2013) (Almami et al., 2012) (Almami et al., 2013) (Almami, Juric & Ahmed, 2014) (Almami, Juric & Zaki Ahmed, 2015) (Almami et al., 2015).

4.4 Research Breakthrough

The core of this research is the LeSMM of the Computational Model. It is this layer of the software architecture that sets the foundation for any reasoning that will take place to support, in the most appropriate way, a user with LD. Therefore, it was felt not only worthwhile but also necessary to spend some time identifying the alternatives.

A good software engineering solution is often determined by the extent of interactions required from a user. Having this in mind, led us to revisit the structure of data-property intensive ontology required for the representation of learning spaces. The more ontology concepts entail eventually the more input from user. Considering also that the ultimate users are pupils with LD and instructors in an educational institution, and that the duration of any teaching session is limited, there is not enough time to be spared for extensive interaction with a system only to prepare the environment for teaching and learning.

In the author's earlier experience, ontological structures were heavily dependent on data properties (Almami & Juric, 2011b).

Considering the fact that broad use of data properties in ontological classes would require extensive user input to insert values for data properties that are dynamically defined, it was necessary to move away from data property insertions.

This observation has resulted switching to object properties as a dominant factor besides classes of the ontology. When data properties are used, the emphasise of the model is on individuals of classes, but when the attention is more towards the relationships between individuals of classes then data type properties should give way to object properties.

The author has briefly pointed out what object properties are in Chapter 2 and also section 4.3.1 in this chapter. However, in view of the reliance of the rest of this chapter on object properties, it is worth mentioning a few words about these properties. Unlike data properties that define individuals of a class, object properties define relationships between individuals of two classes.

It is the OP that determines who/what should be the object and who/what should be the subject of the relationship. In other words, once an OP is defined, for any instance of the OP, it can be inferred without any hesitation what class the object and the subject of the relationship are member of.

The universality of OP that once it is used the class membership of individuals at each side of the relationship is known, and that object properties are unique within the ontology, it makes models more reusable comparing with data-property oriented ontologies. Or formally expressed as:

$$\forall R.C : \{per | \forall i R(per, i) \rightarrow i \in C\}$$

Where R is an object property, C is a concept at the end side of the relationship (or OP), per is an individual at one side of the object property, and i is an individual at the other side of the object property.

In addition to moving from data property to OP, ways of reducing number of classes required for representing any learning space need to be found.

This could not be possibly overlooked as it would have negatively impacted the end result, i.e. users would have to input endless amount of information to start off the system. Therefore, the attention to OP and less ontology classes whilst not sacrificing necessary data was a breakthrough. In the following subsections the journey from the first design taking this approach to the last one, on which the implementation in the following chapter is based, are explained.

4.4.1 New Design Foundation Classes

We had to agree on a set of minimum number of classes without which the representation of the learning space would be impossible. At the centre, of course, is the user, or in this case LD pupils who have been represented in a more generic term *PERSON*. Therefore, *PERSON* is the first class in the foundation set of classes in the LE?:

$$C\Delta = \{PERSON\}$$

The driving motivation behind this research has been serving pupils with impairments. Therefore there must be a class to accommodate different types of impairment, hence the class *IMPAIRMENT*:

$$C\Delta = \{PERSON, IMPAIRMENT\}$$

There are specifically defined practices associated with each kind of impairment. There might be several practices that suit a particular impairment, or a specific practice might serve several impairments. This, therefore, suggests another class, *PRACTICE*.

$$C\Delta = \{PERSON, IMPAIRMENT, PRACTICE\}$$

At any given time a pupil with LD may require different need. In other words, they may have different goals to attend to in different sessions. The model should address this requirement. It was named as *GOAL* as the fourth and last class in the foundation set. Therefore, the complete foundation set C for the $LE\Delta$ contains four classes:

$$C\Delta = \{PERSON, IMPAIRMENT, PRACTICE, GOAL\}$$

It has to be added that the above classes of $C\Delta$ individuals are disjoint classes with respect to the T-Box T. That is the intersection of each two pairs results in an empty set as shown in Figure 4.10.

PERSON Π IMPAIRMENT = Ø

PERSON Π PRACTICE = Ø

PERSON Π GOAL = Ø

IMPAIRMENT Π PRACTICE = Ø

IMPAIRMENT Π GOAL = Ø

PRACTICE Π GOAL = Ø

Fig. 4.10 Empty Sets of Disjoints Classes of $C\Delta$

In summary, following the implementation of several models addressing different competency questions, it became evident that rearranging some of the high level classes and asserting all possible individuals inside these classes, the above foundation, will represent the environment as well as the earlier models.

Considering that the new model is much simpler than the earlier model and believing that good solutions are usually the simple ones, the decision was made.

As a result of this decision, as will be shown later, the set of rules imposed upon ontological classes became shorter.

4.4.1.1 Design 1

In this model the ontological structure was based only on the foundation set, $C\Delta$ as shown in Figure 4.11.

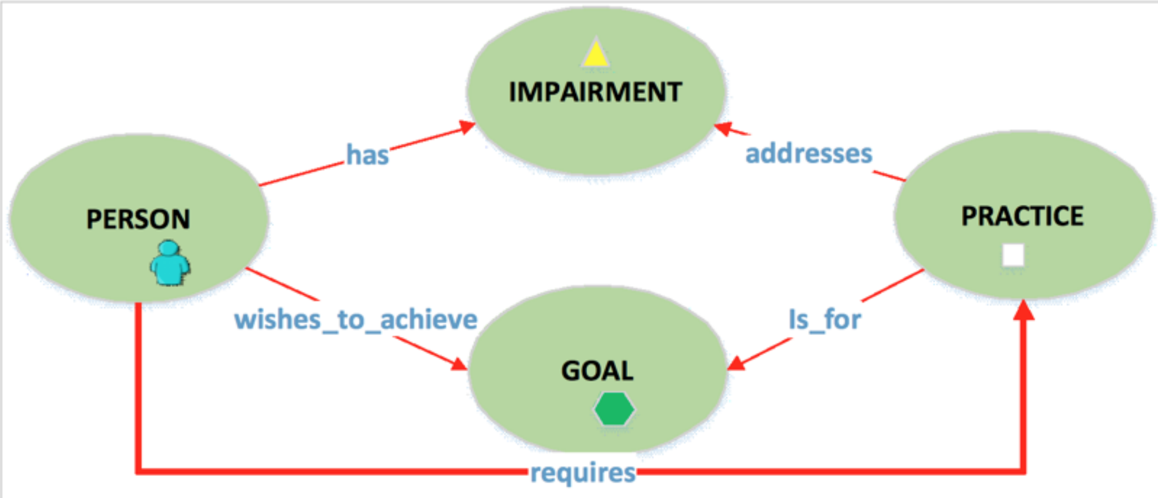


Fig. 4.11 Design 1

In this model, for example, the relationships between individual of *PERSON* and an individual (or individuals) of *IMPAIRMENT* are made through an object property "has". The *IMPAIRMENT* class represents all possible individuals of impairments, and *PERSON* represents general characteristics of user who will be seeking practices they need for their impairments. The other object properties are also self-explanatory. Object properties with the domain and range for Design 1 were defined as shown in Table 4.1.

Table 4.1 Object Properties of Design 1

Object Property	**Domain**	**Range**
has	PERSON	IMPAIRMENT
wishes_to_achieve	PERSON	GOAL
addresses	PRACTICE	IMPAIRMENT
is_for	PRACTICE	GOAL
requires	PERSON	PRACTICE

The first four object properties are T-Box T axioms which are expressed in Description Logic format in Figure 5.8

The OP " requires" is not asserted originally as an element of the T-Box T axioms. It is inferred as a result of running a reasoning tool. This will be explained further in this section.

$$\forall per(\mathrm{PERSON}(per) \rightarrow \exists i\ (\mathrm{IMPAIRMENT}(i) \land \mathrm{has}\ per\ i))$$
$$\forall per(\mathrm{PERSON}(\mathrm{per}) \rightarrow \exists g\ (\mathrm{GOAL}(g) \land \mathrm{wishes\_to\_achieve}\ per\ g))$$
$$\forall p(\mathrm{PRACTICE}(p) \rightarrow \exists i\ (\mathrm{IMPAIRMENT}(i) \land \mathrm{addresses}\ p\ i))$$
$$\forall p(\mathrm{PRACTICE}(p) \rightarrow \exists g\ (\mathrm{GOAL}(g) \land \mathrm{is\_for}\ p\ g))$$

Fig. 4.12 Description Logic Format of Table 4.1

In subsequent figures and in all designs to follow, an arrow, which represents an OP always, starts from a domain and ends at the range of the OP. So, the arrow head always rests at the range side.

In this design the author avoids having any classes that play the role of a temporary position for moving individuals. One of design patterns in ontological modelling is to copy individuals that belong to a particular class into another class as a result of running some rules. This effectively define an individual to belong to several classes. So, in the first attempt it was decided that it would be best not to have any extra classes, other than the foundation set.

For clarification, some examples of the, $C\Delta$ individuals $(i \in C\Delta)$ are shown below and also summarised in Figure 4.13.

$$\{PERSON, IMPAIRMENT, PRACTICE, GOAL\}$$

- **PERSON** ={alice, bob, david, eve, jack, lucy, sarah}.
- **IMPAIRMENT** ={autism, asperger_syndrome, ADD/ADHD, difficulty_with_change_in_routine, dyslexia, dyspraxia, lacks_tact, lack_of_organasation_skills}.
- **GOAL** = {learning_colours, learning_shapes, learning_dance, learning_music, learning_social_interaction_skils, learning_categories, learning_numerals, learning_sequencing_and_order, learning_reading, learning_science, learning_writing}.
- **PRACTICE** = {analyse_the_information, place_pictures_on_containers, maintain_lists_of_assignments, place_pictures_on_containers, place_pictures_on_locker, use_of_highlighters, use_colour_coding, use_rewards_and_motivation, use_picture_cues_in_locker, use_rewards_and_motivation, use_schedules, use_set_of_printable_colour_worksheets, use_social_skills, use_social_stories,

Use_sorting_object, use_simple_drawings, use_accessible_pictorial, use_written_rules_to_remind, use_objects_of_reference, use_checklists, use_strength, use_calenders, use_lists, use_basic_maching_for_colour}.

- **TECHNOLOGY** = {adaptive_hardware, board_maker, books_on_tape, calculators, cameras, colour_coding_files_or_drawers, complex_voice_output, computer_generated_virtual_objects, computer_screen_complex_or_high-tech, computers, dry_erase_boards_clipboards, graphic_organizers, highlightt_ape, master_overhead_projector, photo_albums_laminated_PCS/photographs, software, tape_recorder_Language, tape_recorders, use_audio_taped, use_of_highlighter_tool_on_computer_highlighters, various_visual_systems, video, virtual_character, visual_support_strategies, voice_recognition }.

CLASS	INDIVIDUALS
PERSON	alice, bob, david, eve, jack, lucy, sarah.
IMPAIRMENT	autism, asperger_syndrome, ADD/ADHD, difficulty_with_change_in_routine, dyslexia, dyspraxia, lacks_tact. lack_of_organasation_skills,
GOAL	learning_colours, learning_shapes, learning_dance, learning_music, learning_social_interaction_skils, learning_categories, learning_numerals, learning_sequencing_and_order, learning_reading, learning_science, learning_writing.
PRACTICE	analyse_the_information, place_pictures_on_containers, maintain_lists_of_assignments, place_pictures_on_containers, place_pictures_on_locker, use_of_highlighters, use_colour_coding, use rewards_and_motivation, use_picture_cues_in_locker, use_rewards_and_motivation, use_schedules, use_set_of_printable_colour_worksheets, use_social_skills, use_social_stories, Use_sorting_object, use_simple_drawings, use_accessible_pictorial, use_written_rules_to_remind, use_objects_of_reference, use_checklists, use_strength, use_calenders, use_lists, use_basic_maching_for_colour.
TECHNOLOGY	adaptive_hardware, board_maker, books_on_tape, calculators, cameras, colour_coding_files_or_drawers, complex_voice_output, computer_generated_virtual_objects, computer_screen_complex_or_high-tech, computers, dry_erase_boards_clipboards, graphic_organizers, highlight_tape, master_overhead_projector, photo_albums_laminated_PCS/photographs, software, tape_recorder_Language, tape_recorders, use_audio_taped, use_of_highlighter_tool_on_computer_highlighters, various_visual_systems, video, virtual_character, visual_support_strategies, voice_recognition.

Fig. 4.13 Some Sample Individuals for Core Classes

Based on the above individuals one of the earlier T-Box T axioms, for example,

$$\forall \text{ per}(\text{PERSON}(\text{per}) \rightarrow \exists i(\text{IMPAIRMENT}(i) \wedge \text{ has per } i))$$

can be written in real terms as three separate assertions in the A-Box A:

PERSON (bob), IMPAIRMENT (autism), has (bob, autism)

The first two where there is only one argument, each is an assertion of an individual indicating that "bob" is a member of the class *PERSON* and autism is a member of the class *IMPAIRMENT*. The third one is an assertion of a binary relationship between two individuals, bob and autism, through the relationship (or OP) "has".

With regards to the object property "requires" as said earlier there is no pre-existing axiom in T-Box T. It is inferred as a result of some reasoning mechanism. As there is no intervening classes to have a step-wise reasoning, all classes and object properties used in Design 1 take part in a single rule at once. This single rule in SWRL is shown below

GOAL(?g) ∧ IMPAIRMENT(?i) ∧ PERSON(?per) ∧ PRACTICE(?p)∧
addresses(?p, ?i) ∧ has(?per, ?i) ∧ is for(?p, ?g) ∧ wishes to achieve (?per,?g)
-> requires (? per, ?p)

The above SWRL rule shows that the antecedent elements of the rule are either an individual of any of the four foundation set classes $C\Delta$, or are an instance of object properties, "has", "addresses", "wishes_to_achieve", or "is for". The result of the reasoning, the consequent, is a new instance of an object property "requires", which relates an individual of *PERSON* to and individual of *PRACTICE*, for example requires (bob, use_sorting_object).

In Section 2.6.2 SWRL rules have been briefly explained. Here, it is worth adding that where there is only one argument present, like in *GOAL(?g)* in which there is only "?g", then the variable, in this case "g" is referring to an individual of a class. Where there are two variables present as arguments, like in has(?*per*, ?*i*), the first one, "*per*" in this case, refers to a domain object and the second, "i" in this case, refers to a range subject. In this case "has" would be the predicate of the relationship or in OWL terminology the object property.

Because no filtering is done at different stages of reasoning and all the filtering is done in one stage through one SWRL rule, the time it takes to run the rule when the number of individuals populating *IMPAIRMENT* and *PRACTICE* classes becomes considerably large will be too long. This deficiency has resulted moving to Design 2.

4.4.1.2 Design 2

In this model as Figure 4.14 shows the foundation set *C*Δ is intact, but three more classes have been added to the *LE*Δ. These classes are *PERSON_IMPAIRMENT*, *IMPAIRMENT_PRACTICE*, and *GOAL_PRACTICE*. While still the *C*Δ classes or concepts are disjoint classes as explained in 4.4.1, the above new concepts are defined below with respect to *T*: *PERSON_IMPAIRMENT*: it is disjoint with all other concepts of *T* but the *IMPAIRMENT* concept. It is a subclass of *IMPAIRMENT* so:

PERSON_IMPAIRMENT Π PERSON = Ø
PERSON_IMPAIRMENT Π PRACTICE = Ø
PERSON_IMPAIRMENT Π GOAL = Ø
PERSON_IMPAIRMENT Π *IMPAIRMENT_PRACTICE* = Ø
PERSON_IMPAIRMENT Π *GOAL_PRACTICE* = Ø
PERSON_IMPAIRMENT ⊑ IMPAIRMENT

Fig. 4.14 The Relationships Between *PERSON_IMPAIRMENT* and other Concepts of *T*

IMPAIRMENT PRACTICE: it is disjoint with all other concepts of *T* but the *PRACTICE* and *GOAL_PRACTICE* concepts. It is a subclass of *PRACTICE* and super class of *GOAL_PRACTICE* as Figure 4.15 Figure 4.15 so:

IMPAIRMENT_PRACTICE Π PERSON = Ø
IMPAIRMENT_PRACTICE Π GOAL = Ø
IMPAIRMENT_PRACTICE Π IMPAIRMENT = Ø
IMPAIRMENT_PRACTICE Π PERSON_IMPAIRMENT = Ø
IMPAIRMENT_PRACTICE ⊑ PRACTICE
GOAL_PRACTICE ⊑ IMPAIRMENT_PRACTICE

Fig. 4.15 The Relationships Between *PERSON_PRACTICE* and other Concepts of *T*

One of the axioms has been highlighted in grey to indicate that it has already been expressed.

GOAL_PRACTICE: it is disjoint with all other concepts of *T* but the *PRACTICE* and *IMPAIRMENT_PRACTICE* concepts. It is a subclass of *PRACTICE* and *IMPAIRMENT_PRACTICE* as Figure 4.16 so:

$$\text{GOAL\_PRACTICE} \sqcap \text{PERSON} = \emptyset$$
$$\text{GOAL\_PRACTICE} \sqcap \text{GOAL} = \emptyset$$
$$\text{GOAL\_PRACTICE} \sqcap \text{IMPAIRMENT} = \emptyset$$
$$\text{GOAL\_PRACTICE} \sqcap \text{PERSON\_IMPAIRMENT} = \emptyset$$
$$\text{GOAL\_PRACTICE} \sqsubseteq \text{PRACTICE}$$
$$\text{GOAL\_PRACTICE} \sqsubseteq \text{IMPAIRMENT\_PRACTICE}$$

Fig. 4.16 The Relationships Between *GOAL_PRACTICE* and other Concepts of *T*

Two of the axioms have been highlighted in grey in figure 4.16 to indicate that they have already been expressed.

The four classes of $C\Delta$, (green in Figure 6) have individuals as domain knowledge prior to the reasoning process, whereby the brown classes initially have no individuals but as the result of reasoning they will be populated with individuals. For example, by inserting an individual for has (? *per*, ? *i*) a relationship between a real individual of PERSON and a real individual of *IMPAIRMENT* is established:

PERSON (*bob*), IMPAIRMENT (*autism*), has (*bob*, *autism*)

In Figure 4.17, the black lines and the green arch are for graphical explanation and have no ontological significance. The black lines depict the head of a big arrow and indicate that as a consequence of relationship between the individual of classes at the tail individual(s) of the class at the head is generated. The green arch, on the other hand, shows copying of an individual from one class into another.

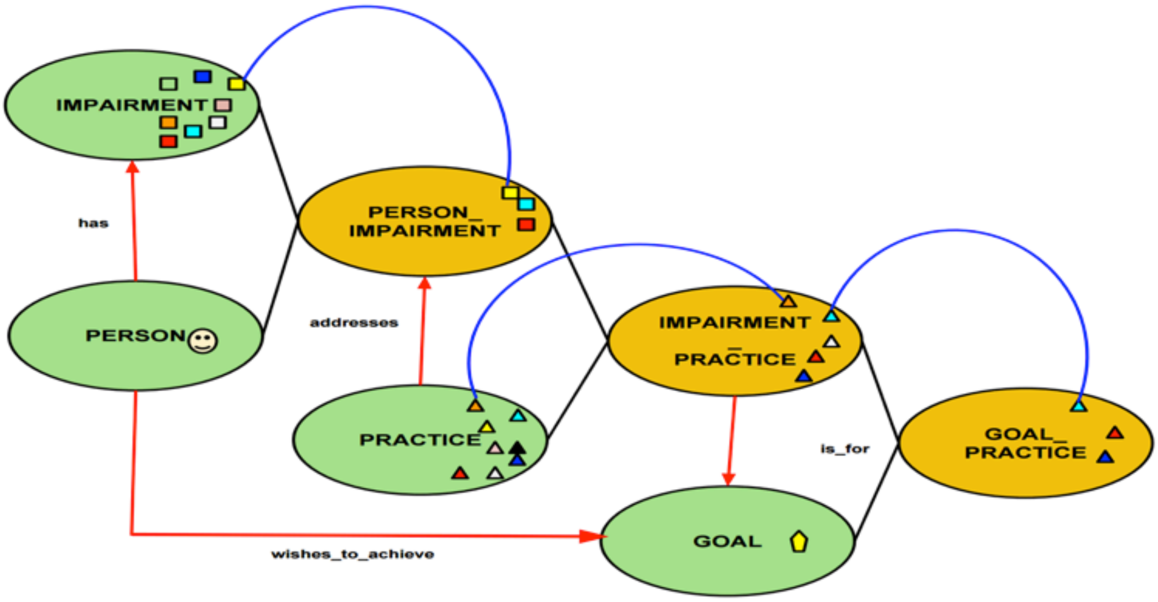


Fig. 4.17 Design 2 reasoning proces

The object property definitions for this design is summarised in Table 4.2.

As shown, comparing with Design 1, there are only four object properties rather than five and the has and wishes to achieve OP are defined as before. The range of addresses and the domain of is-for are changed as shown highlighted in Table 4.2

Table 4.2 Object Properties of Design 2

Object Property	**Domain**	**Range**
has	PERSON	IMPAIRMENT
wishes_to_achieve	PERSON	GOAL
addresses	PRACTICE	PERSON_IMPAIRMENT
is_for	IMPAIRMENT_PRACTICE	GOAL

The reasoning mechanism to infer an individual of *PERSON_IMPAIRMENT* is done by running the following SWRL rule:

IMPAIRMENT(?i), PERSON(?per), has(?per, ?i) -> PERSON_IMPAIRMENT(?i)

Therefore, individuals belonging to *PERSON_IMPAIRMENT* are a copy of some of the individuals that are member of *IMPAIRMENT* class by applying the above SWRL rule.

This class, *PERSON_IMPAIRMENT*, will therefore contain all impairments of an individual variable "*per*" of *PERSON*. This is exactly the following axiom mentioned earlier

PERSON_IMPAIRMENT $\sqcap$ IMPAIRMENT

Likewise through the following rule some of the individuals of *PRACTICE* are moved to *IMPAIRMENT_PRACTICE*:

PERSON_IMPAIRMENT(?*pi*), PRACTICE(?*p*), addresses(?*p*, ?*pi*)
->IMPAIRMENT_PRACTICE(? *p*)

which is a reflection of the earlier axiom IMPAIRMENT_PRACTICE $\subseteq$ PRACTICE. The IMPAIRMENT_PRACTICE (?p) will provide all practices for all impairments, but only those that match the person's goals are of interest.

The following rule filters out any practices that do not match with the concerned person's goals.

As before this is also a reflection of of T axiom GOAL_PRACTICE $\subseteq$ IMPAIRMENT_PRACTICE.

Unlike the previous design in which an object property that links an individual of PERSON to an individual of *PRACTICE* is inferred as a result of the reasoning process, in this design an individual is moved to the class *GOAL_PRACTICE* as the final result.

In the first two models the technology was deliberately left aside basically because of knowing once the required practice for a particular goal is known, the technology suitable for the practice can be computed in a straightforward manner. In the third design below, technology is included in the ontological model.

4.4.1.3 Design 3

In the earlier design models the set of foundation concepts $C\Delta$ were limited to *PERSON*, *IMPAIRMENT*, *PRACTICE*, and *GOAL*. Therefore, in the previous two models there was no representation of technologies used in each practice. As individual technologies available in any environment can be asserted as known in the environment ontological repository, the set of foundation classes can be extended to include technology too as shown below and depicted in Figure 4.18.

$$C\Delta = \{\text{PERSON, IMPAIRMENT, PRACTICE, GOAL, TECHNOLOGY}\}$$

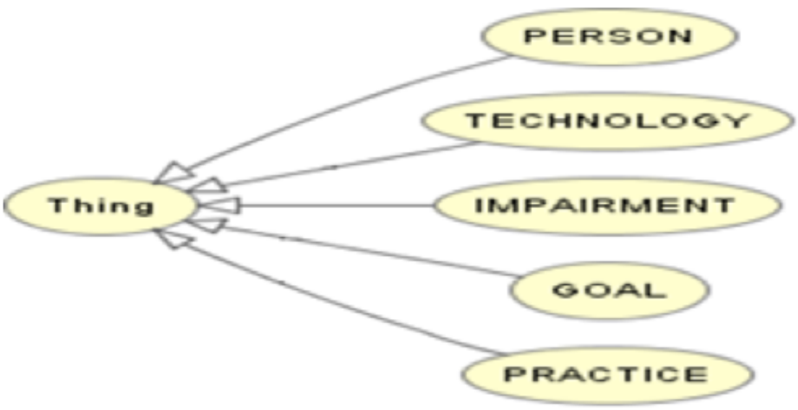


Fig. 4.18 Basic Ontological Classes for the DMM

These classes represent individuals which describe the semantics relevant to people, impairments they may have, learning goals they wish to achieve, teaching practices essential for achieving such goals, and technologies that are available for use or are needed for addressing the specified goal. This research ultimate ontological design is shown in Figure 4.19.

In this model once the result of the reasoning process explained in Design 2 is completed, that is once the individual or individuals of the class *GOAL_PRACTICE* are known, in one step further the required technology for the particular practice can be identified.

As this design is the final design that this thesis is proposing, a comprehensive list of axioms (36 in total) which accommodates all the axioms in previous models plus new ones are presented in below Figure 4.20 below:

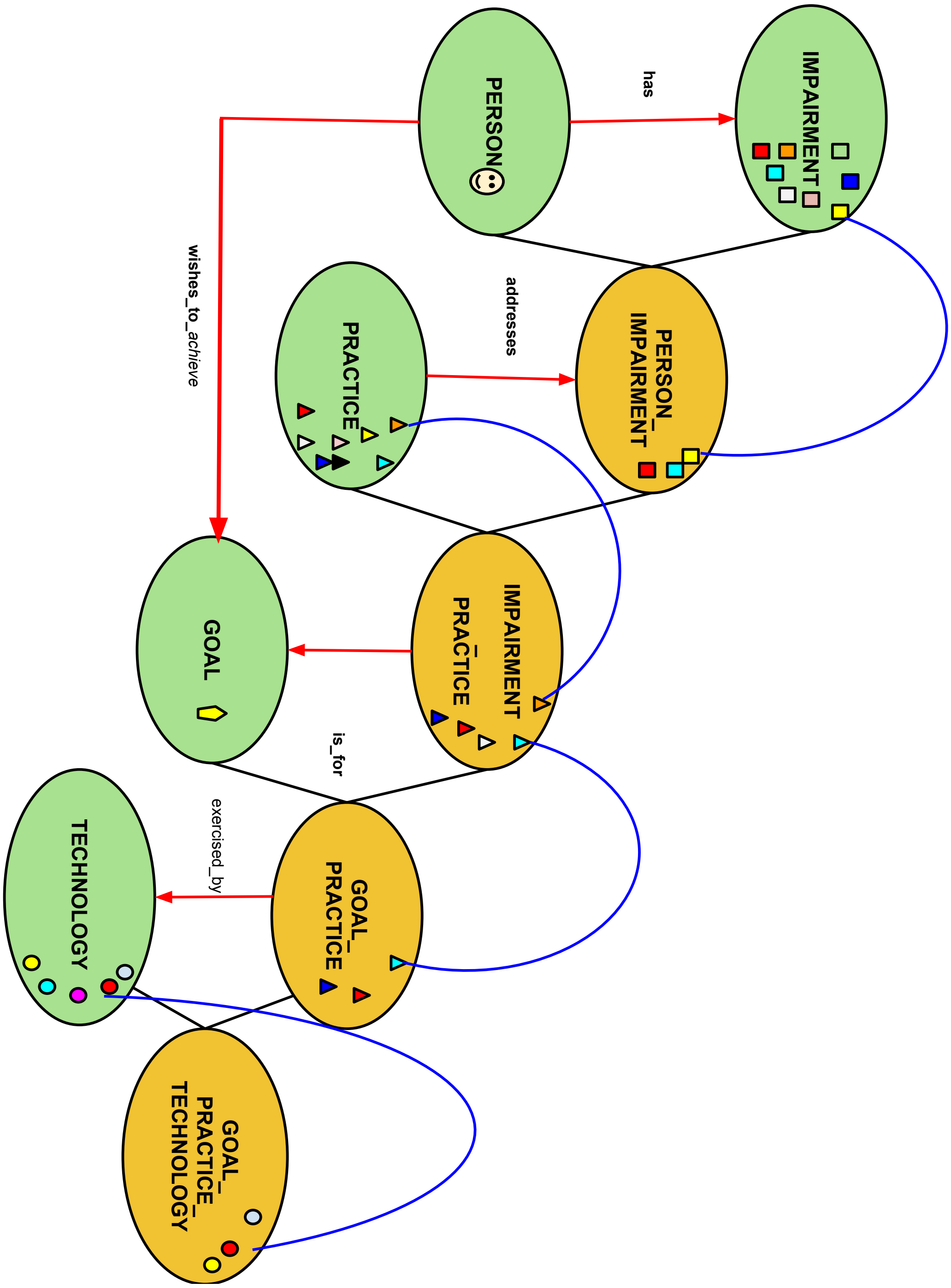


Fig. 4.19 Design 3 Reasoning Process

PERSON ⊓ IMPAIRMENT ≡ Ø
PERSON ⊓ PRACTICE ≡ Ø
PERSON ⊓ GOAL ≡ Ø
PERSON ⊓ TECHNOLOGY ≡ Ø
IMPAIRMENT ⊓ PRACTICE ≡ Ø
IMPAIRMENT ⊓ GOAL ≡ Ø
IMPAIRMENT ⊓ TECHNOLOGY ≡ Ø
PRACTICE ⊓ GOAL ≡ Ø
PRACTICE ⊓ TECHNOLOGY ≡ Ø
GOAL ⊓ TECHNOLOGY ≡ Ø
PERSON_IMPAIRMENT ⊓ PERSON ≡ Ø
PERSON_IMPAIRMENT ⊓ PRACTICE ≡ Ø
PERSON_IMPAIRMENT ⊓ GOAL ≡ Ø
PERSON_IMPAIRMENT ⊓ TECHNOLOGY ≡ Ø
PERSON_IMPAIRMENT ⊓ IMPAIRMENT_PRACTICE ≡ Ø
PERSON_IMPAIRMENT ⊓ GOAL_PRACTICE ≡ Ø
PERSON_IMPAIRMENT ⊓ GOAL_PRACTICE_TECHNOLOGY ≡ Ø
PERSON_IMPAIRMENT ⊑ IMPAIRMENT
IMPAIRMENT_PRACTICE ⊓ PERSON ≡ Ø
IMPAIRMENT_PRACTICE ⊓ GOAL ≡ Ø
IMPAIRMENT_PRACTICE ⊓ IMPAIRMENT ≡ Ø
IMPAIRMENT_PRACTICE ⊓ TECHNOLOGY ≡ Ø
IMPAIRMENT_PRACTICE ⊓ GOAL_PRACTICE_TECHNOLOGY ≡ Ø
IMPAIRMENT_PRACTICE ⊑ PRACTICE
GOAL_PRACTICE ⊑ IMPAIRMENT_PRACTICE
GOAL_PRACTICE ⊓ PERSON ≡ Ø
GOAL_PRACTICE ⊓ GOAL ≡ Ø
GOAL_PRACTICE ⊓ IMPAIRMENT ≡ Ø
GOAL_PRACTICE ⊓ TECHNOLOGY ≡ Ø
GOAL_PRACTICE ⊓ GOAL_PRACTICE_TECHNOLOGY ≡ Ø
Goal_PRACTICE ⊑ PRACTICE
GOAL_PRACTICE_ TECHNOLOGY ⊓ PERSON ≡ Ø
GOAL_PRACTICE_ TECHNOLOGY ⊓ GOAL ≡ Ø
GOAL_PRACTICE_ TECHNOLOGY ⊓ IMPAIRMENT ≡ Ø
GOAL_PRACTICE_ TECHNOLOGY ⊓ PRACTICE ≡ Ø
GOAL_PRACTICE_TECHNOLOGY ⊑ TECHNOLOGY

Fig. 4.20 Design 3 Axiom

As Table 4.3 shows object property exercised by can have an individual of *GOAL_PRACTICE* which is effectively an individual of a *PRACTICE* as its domain, and an individual of *TECHNOLOGY* as its range. All other object properties of Design 2 have been carried forward to Design 3. The relationships are expressed formally in figure 5.12.

Table 4.3 Object Properties of Design 3

Object Property	**Domain**	**Range**
has	PERSON	IMPAIRMENT
wishes_to_achieve	PERSON	GOAL
addresses	PRACTICE	PERSON_IMPAIRMENT
is_for	IMPAIRMENT_PRACTICE	GOAL
exercised_by	GOAL_PRACTICE	TECHNOLOGY

$$\forall per(\text{PERSON}(per) \rightarrow \exists i\ (\text{IMPAIRMENT}(i) \wedge \text{has}\ per\ i))$$
$$\forall per(\text{PERSON}(per) \rightarrow \exists g\ (\text{GOAL}(g) \wedge \text{wishes\_to\_achieve}\ per\ g))$$
$$\forall p(\text{PRACTICE}(p) \rightarrow \exists i\ (\text{PERSON\_IMPAIRMENT}(i) \wedge \text{addresses}\ p\ i))$$
$$\forall p(\text{IMPAIRMENT\_PRACTICE}(p) \rightarrow \exists g\ (\text{GOAL}(g) \wedge \text{is\_for}\ p\ g))$$
$$\forall p(\text{GOAL\_PRACTICE}(p) \rightarrow \exists g\ (\text{TECHNOLOGY}(g) \wedge \text{exercised\_by}\ p\ g))$$

Fig. 4.21 Object Properties of Design 3 in DL Format

Having identified individuals of *PRACTICE* suitable for a particular *GOAL_PRACTICE(?gp)* in Design 2 , extending the chain of rules one more step will identify required technology. The SWRL rule to reason required technology for the particular learning practice considering the goal of the user who has some particular impairments is shown below:

GOAL_PRACTICE(?gp) ∧ TECHNOLOGY (?t) ∧ exercised_by (?gp, ?t)
-> GOAL_PRACTICE_TECHNOLOGY(?t)

Therefore, through a number of axioms in the T-Box T and assertions in the A-Box A and applying reasoning mechanism upon the axioms given the facts of the knowledge base, it has been demonstrated how the objectives of assisting students with learning difficulties to achieve their particular goals can be met through identifying appropriate learning practices and technologies that are used for them

4.5 Summary

In this section a detailed explanation is provided to set out Design Models 1, 2 and 3 of the ontological model. These 3 models were specifically developed in the light of current research and the limitations of existing models, with the aim of improving provision for LD learners. Clear diagrams are provided to show the mechanics of each separate design model and how it can be implemented. The proposed model is innovative and a departure from existing models, based on learner needs. In the following chapter these achievements will be illustrated through some real examples

The three designs all considered different approaches. In Designs 1 and 2 it was quite straightforward to compute the practice, therefore it was decided to leave the technology aside. Design 1 took a long time to run the rule, because there was no filtering done at different stages of reasoning. Instead all of the filtering was in one stage. In Design 1 there were 5 object properties, compared to Design 2, which had only 4. Also, in Design 2 there are 3 filters, instead of just one, with the result that it speeds up the process. As this design is the final design that this thesis is proposing, a comprehensive list of axioms (36 in total) which accommodates all the axioms in previous models plus new ones.

To improve on Designs 1 and 2, in Design 3, it was decided to include the ontological model. This was decided because of the realisation that in the earlier 2 designs, there was no representation of technologies used. In the following chapter these achievements will be illustrated through some real examples, using Java technologies, and OWL API.

Chapter 5

The Implementation of the Proposed Model

A detailed description of this thesis proposal was provided in the previous chapter. Here, an illustration of the proposal is provided through the implementation of a particular scenario in a specific educational environment using semantic Web technologies. It has to be pointed out that as the implementation is primarily for proofing a concept, the application was developed as a standalone application. The objective of the chapter is to show that it is possible to create a software application, which can have the proposed computational model at its core. Application of the computational model in mobile devices or running the software application in cloud is more relevant to the intrinsic nature of mobile technologies rather than the computational model. Therefore, a presentation of the use of the computational model in any form should be sufficient to show the capability and practicality of the model.

5.1 The Domain

To present the appropriateness of the proposed computational model, a particular domain needed to be selected. Considering the objectives of the research including managing the semantics of learning environments and the configuration of learning spaces by identifying the needs of learners who have a range of differences in learning, it was a straight forward decision to go for a scenario in education domain. In the following paragraphs a particular educational institution is described.

Education For all Academy (EFA) is a secondary institution that promotes 'education for everyone' despite their learning difficulties. All students at EFA are required to have a year plan. For students under 12 years old the year plan is set by their year-tutors. Those over 12 years old are required to prepare their plan and get it approved by their year-tutor. In these year plans some goals are set; these can be initiated either by the tutor or the student. Tutors monitor their student's progress throughout the year continuously.

EFA is highly valued for its persistence in helping students to achieve their goals. To ensure that students reach their goals successfully EFA has to consider student's circumstances and requirements. Accommodating students with learning impairments can be complex and challenging. The problem is exacerbated when there is a diverse range of impairments among students each requiring different attention.

EFA is currently using a manual system to check which learning practices suit students the best, in order to reach their target. However, considering the increasing number of students with learning difficulties, EFA prefers to have an automated system in place. This will allow them to identify the best practice and learning programme to address any student's goals, taking into account their specific impairments.

5.1.1 EFA Scenario

Bob, David, Alice and Eve, who are studying at EFA, have some types of learning impairment.

Bob has autism, which means that he faces challenges in terms of his organisational skills. He has difficulty focusing for long periods at a time, and also finds it hard to understand the concepts of Mathematics. He would like to use colours, in order to become more confident with patterns and matching up similar objects or quantities. Bob's year-tutor has set 'learn colours' to be one of Bob's goal for this year.

David has ADD/ADHD. Concentration is therefore a challenge for him. He can become easily distracted, has poor listening skills and can at times, zone out. As a result, forming friendships is difficult. His goal is therefore set by his tutor as 'improve social interaction skills'.

Alice who is a senior student, and should set her own goals for the year, has dyslexia, and has difficulties with retaining information, decoding text and expressing her ideas in writing. Her learning goal is to be able to read information more easily, as she finds it difficult to read quickly because she has to decode the words. Another learning goal is to be able to record her ideas on paper, in preparation for essays and exams. She finds it very difficult to write down her ideas fluently. She would like to use assistive technologies, for example using text-to-speech software and speech-to-text software, as well as software for planning essays, such as mind-mapping programmes. Alice's tutor has approved her goals as 'improve reading skills' and 'improve writing notes'.

Eve is in her final year and has dyspraxia. She has difficulties in getting her work organised and meeting deadlines. She would like to be able to develop strategies for planning, drafting and organising her work. Eve's goal is to overcome her learning difficulties and to find a way to address these issues through the use of technology. This goal has been approved by her tutor as a viable, and rephrased as 'use assistive technologies'.

5.2 Application of Proposed Computational Model

The application is based on the proposed computational model to accommodate the unique learning preferences of each student. The design will allow the person (or user) to go through the interface and record their individual impairment and their learning goals (or these can be inserted by a tutor). This information will be key to generating the appropriate learning practice, which will enable the learners to meet their own specific learning goals. The practice can be replaced with technology, in cases where the learner has demanded a preference for this. In terms of teaching practice, the programme will be designed to take account of the small differences in perception, which are present in a person with a learning impairment. This difference means that the traditional teaching methods a teacher might use, for example, when teaching learners to read, might suit the majority of learners, but may well exclude those with learning differences.

The reference computational model, by carefully recording a person's age, background, interests and learning abilities allows for a more personalised learning programme to be developed. Some learners may find reading difficult due to their concentration difficulties, reading and decoding difficulties, being hyperactive, an inability to make eye contact with the teacher, or to develop relationships effectively, etc. so they will not respond to the same teaching practices as learners without impairments. An alternative learning practice is therefore required to accommodate these learners.

The computational model will offer a choice of technology and software solutions to enhance the learning process. Depending on the precise answers which the learner has given on the interface, an appropriate selection of technologies, which suit their learning, needs and factor in the challenges of their impairment, will be generated. This bespoke learning programme will be much more meaningful because it is personalised and the student is empowered through being given a voice to record their own preferences. It is also beneficial for the instructor, because they will have a class of students of mixed ability, making it difficult to select materials which will be the appropriate level for everyone. By having the option to interact with this reference computational model, they will be able to put differentiation into practice much more easily. The reference computational model describes the process from the exact moment in which a situation is created, until the end of the computation, when a personalised learning programme is generated. The programme offers an alternative solution, by focusing on the strengths and personal learning preferences indicated by the learner themselves, and tailoring an individualised programme to meet their needs. Although all LDs differ, there are some commonalities in terms of information processing difficulties. These include processing information, memory difficulties, expressing ideas – especially in writing, and difficulties with sequential learning. These difficulties can cause the learners to undervalue themselves, have a lack of confidence and feel frustrated. They can also lead to social isolation and under-performance, in terms of the learner's real potential. Verifying the usability and correctness of any ontological model upon which a software application is running a competency question or a series of is needed, as explained in the subsections of 4.3.1 . These questions are aimed at a particular user. This is due to the fact that the ontological model represents the environment and users are inevitably part of the environment.

Therefore, as an inherent part of any competency question, as far as this thesis is concerned, is user. Considering that the ontological model developed through a series of CQs, the application developed upon it should be able to fulfil requirements of any user, whether s/he is Bob, David, Eve or Alice. For example, if the user is David who has Attention Deficit hyperactivity Disorder (ADHD) and his goal set by his tutor is 'improve social interaction skills', the application should be able to identify the correct available practice for David.

5.3 Software Architecture Utilising Ontological Model

To prove that the computational model works effectively in practice it was tested using the scenario above within EFA environment. The high level software architecture at top of which the EFA application sits is shown in figure 5-1 The architecture shows at the front layer the software application built on ontology layer, which incorporates the input from users, i.e. various learners at the EFA institution. The architecture as shown consists of the following main parts:

- Web user interface
- Backend managed bean logic
- Ontology manager component
- OWL API and Pellet reasoner
- Ontology

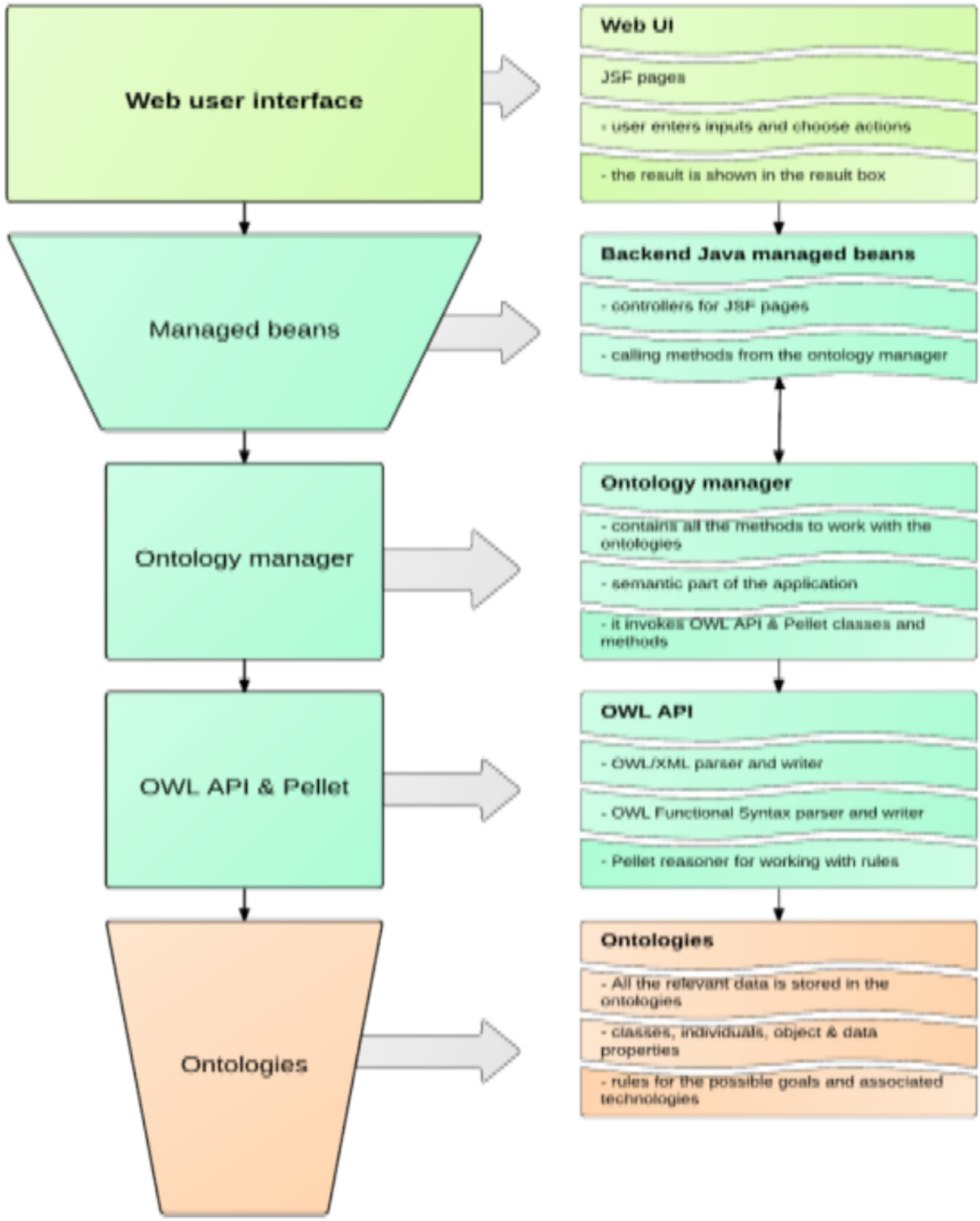


Fig. 5.1 High-level software architecture of the EFA application

These parts are explained in turn in the following sections. The ontology is the core part of the architecture and the part that that this thesis is about, therefore, it will be considered first. This will also help in describing the other parts functionality. Technologies deployed to integrate different parts of the architecture are Netbeans IDE 8.0.2 (Oracle, 2012), JavaServer Faces framework (Jendrock et al., 2014), and OWL API library (Hartel et al., 2005) (Horridge & Bechhofer, 2009) (Liu et al., 2010) (Horridge & Bechhofer, 2011) (Palmisano, 2011) (Knublauch et al., 2004). Further details of these technologies is provided in (Appendix B).

5.4 Ontology

The ontology that provides the foundation for the reasoning process of Design 3, which was explained in Chapter 4, id implemented using Protégé The class hierarchy of classes necessary are shown in Figure 5.2.

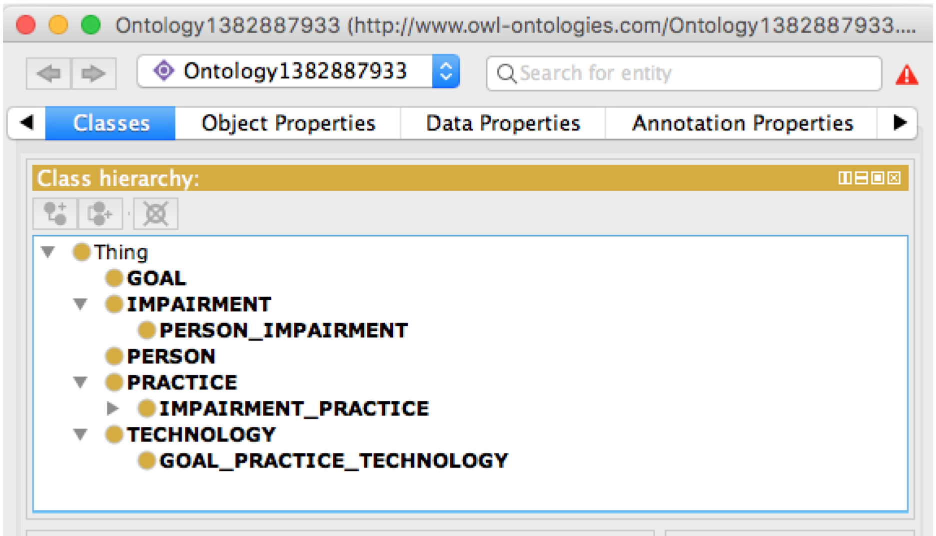


Fig. 5.2 EFA ontology class hierarchy

A more graphical representation of the above hierarchy is depicted in Figure 5.3.

Here the foundation set C= PERSON, IMPAIRMENT, PRACTICE, GOAL, TECHNOLOGY is shown with solid blue line extending from Thing to the five elements of C. Other solid lines also indicate a class-subclass relationship, whereby the arrow shows the subclass. For example the solid line between IMPAIRMENT_PRACTICE and GOAL_ PRACTICE shows that GOAL_ PRACTICE is a subclass of IMPAIRMENT_PRACTICE. The broken line, on the other hand, shows existence of an OP between individuals of classes at either side of the arrow.

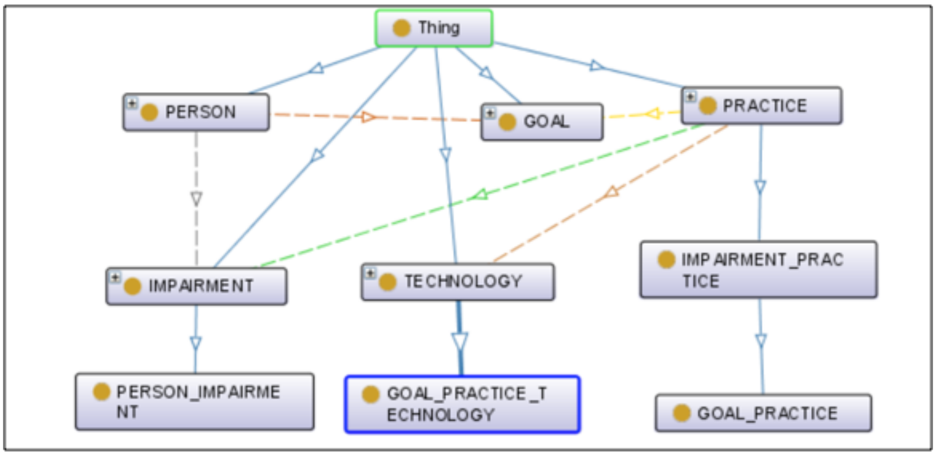


Fig. 5.3 Graphical representation of EFA ontology

The class at the beginning of the arrow shows the domain class and the one at the other end is the range of the OP. For example, as shown in figure 5.4,

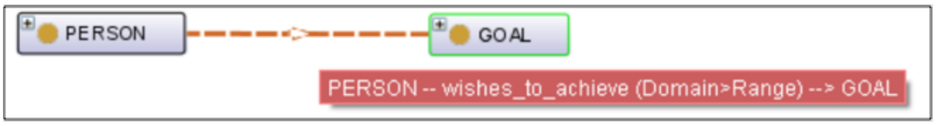


Fig. 5.4 Representation of OP wishes_to_achieve

the orange broken line shows the wishes_to_achieve OP with the domain *PERSON* and range *GOAL*. In Chapter 4, Table 4.3 the object properties are defined as figure 5.5,

$$\forall\, per(\text{PERSON}(per) \rightarrow \exists i\ (\text{IMPAIRMENT}(i) \wedge \text{has}\ per\ i))$$
$$\forall\, per(\text{PERSON}(per) \rightarrow \exists g\ (\text{GOAL}(g) \wedge \text{wishes\_to\_achieve}\ per\ g))$$
$$\forall\, p(\text{PRACTICE}(p) \rightarrow \exists i\ (\text{PERSON\_IMPAIRMENT}(i) \wedge \text{addresses}\ p\ i))$$
$$\forall\, p(\text{IMPAIRMENT\_PRACTICE}(p) \rightarrow \exists g\ (\text{GOAL}(g) \wedge \text{is\_for}\ p\ g))$$
$$\forall\, p(\text{GOAL\_PRACTICE}(p) \rightarrow \exists g\ (\text{TECHNOLOGY}(g) \wedge \text{exercised\_by}\ p\ g))$$

Fig. 5.5 Object Properties of Design 3 in DL Format

These five object properties are implemented as shown in Figure 5.3 in five separate dashed lines between their corresponding classes.

5.4.1 User Interaction

The home page of the EFA application, which is shown in Figure 5.6 offers users the option of choosing the service they require from the EFA application. These questions can be extended to as many as feel necessary, but here just for the purpose of illustration only three questions are provided. These questions are:

- Which teaching/learning practices are available in your learning space?
- Which learning goals are achievable in your learning space using a set of learning/teaching practices?
- Which technologies will be associated with a set of learning/teaching practices in your learning space?

These questions will appear prior to the user identifying themselves or indicating what types of impairments they have.

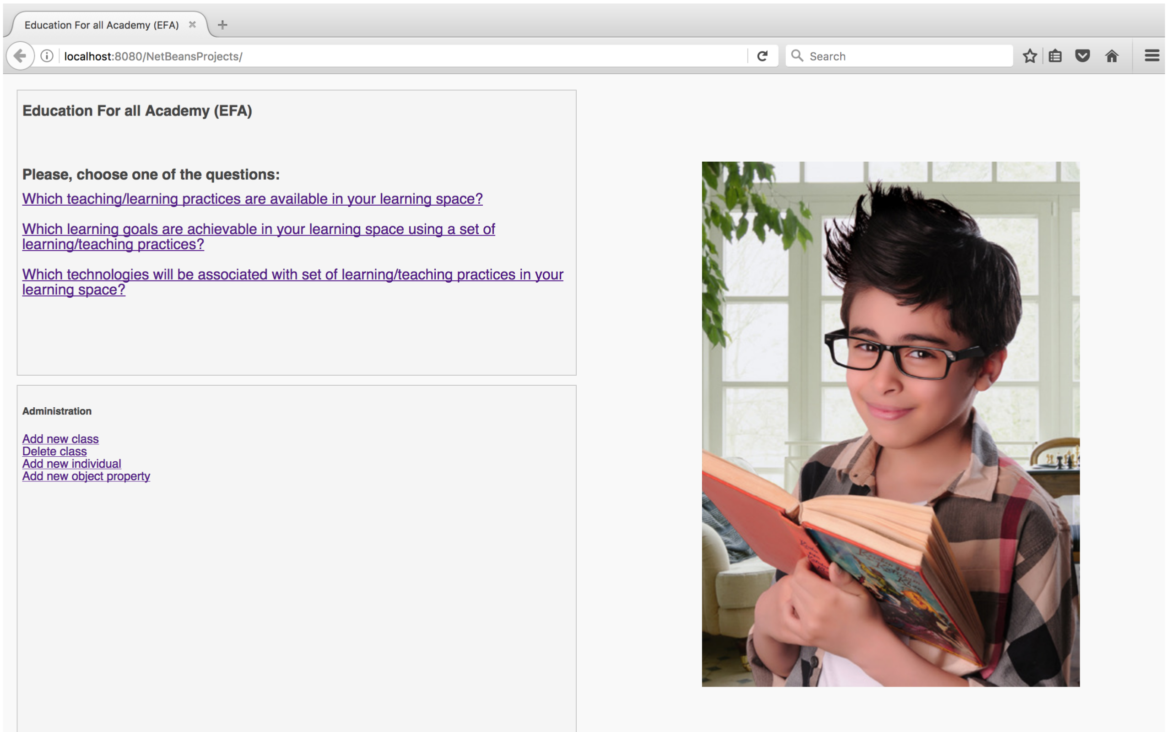


Fig. 5.6 The Main GUI of EFA application

If a user chooses the first question (Which teaching/learning practices are available in your learning space?), s/he is automatically redirected to another page as shown in Figure 5.7, where s/he can enter her/his name, select an impairment from a predefined set of impairments, and choose a goal from another drop down list of possible goals. It has to be added that the impairments and goal drop box choices are dynamically populated using information contained in the ontology. These impairments and goals are individuals of IMPAIRMENT and GOAL classes which have already been asserted and exist in the knowledge base containing both TBox and ABox as explained in Chapter 4.

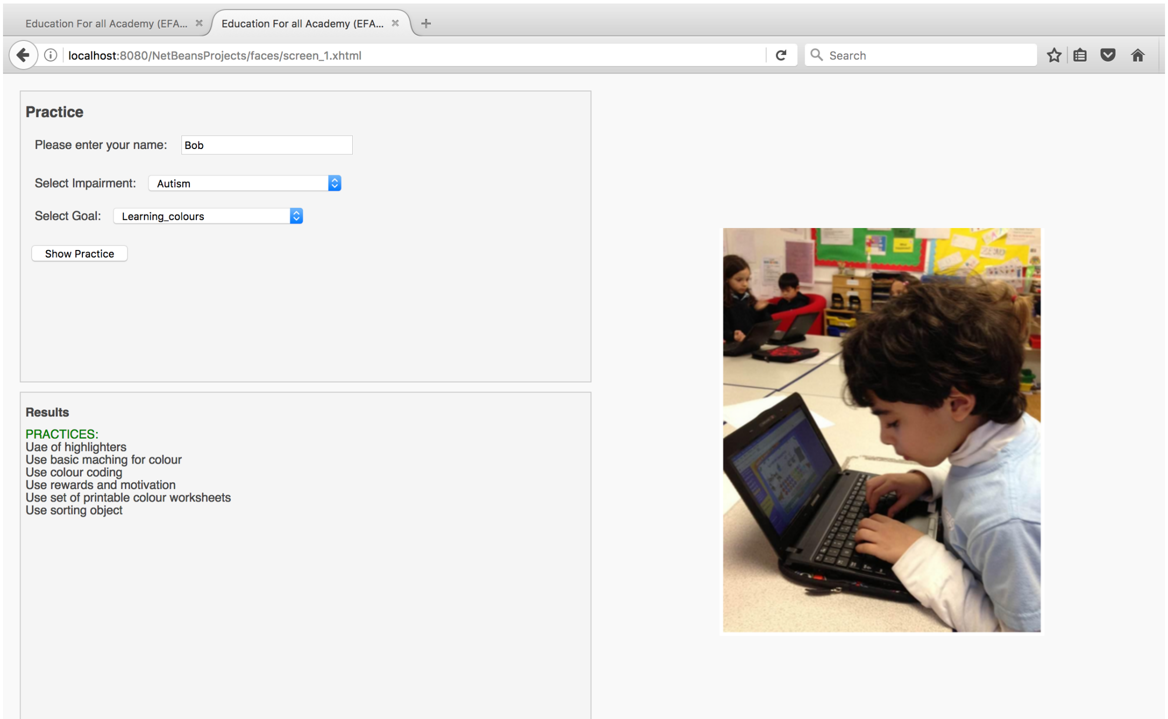


Fig. 5.7 Screen for "Which teaching/learning practices are available in your learning space?"

The indication of individual of *PERSON*, *IMPAIRMENT* and *GOAL* leads to insertion of the associated object properties shown below in Figure 5.8

$$\forall per(\text{PERSON}(per) \rightarrow \exists i\ (\text{IMPAIRMENT}(i) \land \text{has}\ per\ i))$$
$$\forall per(\text{PERSON}(\text{per}) \rightarrow \exists g\ (\text{GOAL}(g) \land \text{wishes\_to\_achieve}\ per\ g))$$
$$\forall p(\text{PRACTICE}(p) \rightarrow \exists i\ (\text{IMPAIRMENT}(i) \land \text{addresses}\ p\ i))$$
$$\forall p(\text{PRACTICE}(p) \rightarrow \exists g\ (\text{GOAL}(g) \land \text{is\_for}\ p\ g))$$

Fig. 5.8 Description Logic Format of Table 4.1

When the user clicks on Show practices button, the result of the reasoning process (in this case practices) will be shown in the second box, as shown in Figure 5.9. The SWRL rule run by the reasoning engine Pellet as explained in Chapter 4, Design 1 is:

GOAL(?g)∧ IMPAIRMENT(?i)∧ PERSON(?per)∧ PRACTICE(?p)∧ addresses(?p, ?i)∧ has(?per, ?i)∧ is_for(?p, ?g)∧ wishes_to_achieve(?per,?g) -> requires(?per, ?p)

As shown in Figure 5.9, all individuals of PRACTICE that match the indicated impairment and goal will be output following the reasoning process using the above SWRL rule. It should be noted that when user input their name, this will be handled by the managed bean layer. The person's name is saved into a variable in the managed bean, whereby the two selected drop-down menus are populated dynamically from the ontology. The managed bean invoke methods from a manager class called OntologyManager.java that works with the ontology utilizing OWL-API: impairmentValues = OntologyManager.getImpairements(ONTOLOGY1_PATH); goalValues = OntologyManager.getGoals(ONTOLOGY1_PATH);

The OntologyManager.java class is central to the EFA semantic Web application, because it defines all the methods that work with the ontology, and uses OWL-API library to implement these functionalities. The complete Java code is attached to the thesis. However, in a nutshell, the OWL ontology model is loaded first, reading a local file. The IMPAIRMENT OWL class is reached using classes and methods provided by OWL-API libraries, and collection of its individuals are retrieved. Next, all the IMPAIRMENT individuals' name are put in *LinkedHashMap* structure required by JSF drop box component, and they are returned as a result of the method, and are now visible in the user interface of the application.

A similar code was used to retrieve all the goals and to populate the relevant drop box in the graphical user interface. Then, appropriate method from the OntologyManager class is extracted to retrieve all the practices available for selected Impairment and Goal. Two object properties addresses and is_for were inspected to extract all the practices associated with selected *IMPAIRMENT* and *GOAL* individuals. If a user chooses the second question (Which learning goals are achievable in your learning space using a set of learning/teaching practices?), user is automatically redirected to another page as shown in Figure 5.9. The user inputs her/his name, chooses an Impairment and clicks on the button Show possible goals.

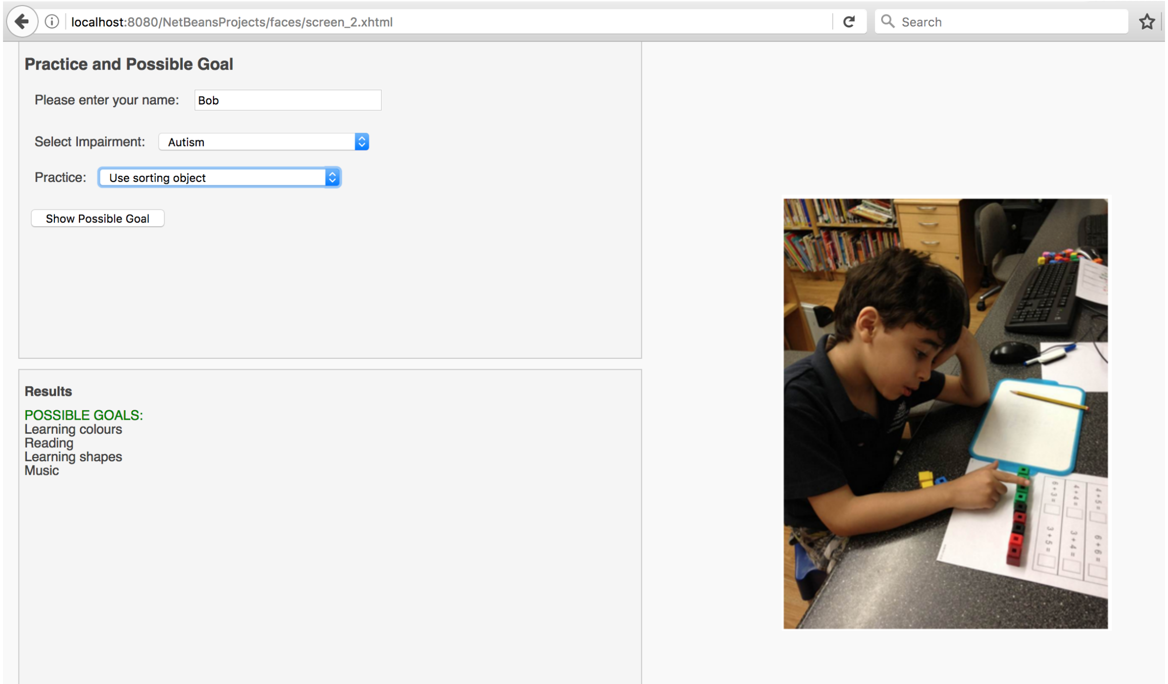


Fig. 5.9 Screen for the question "Which learning goals are achievable in your learning space using a set of learning/teaching practices"

The procedure and code are very similar to that of the previous example, hence no further explanation is necessary. The third option, which demonstrates that the proposed computational model works when all classes of the ontological model are involved, is explained in the following paragraphs. The third page is invoked when user chooses the third question – Which technologies will be associated with set of learning/teaching practices in your learning space? This page shows practices and associated technologies once impairments and goals are stated. The ontology has been asserted with 25 different types of technologies as shown in Figure 5.10.

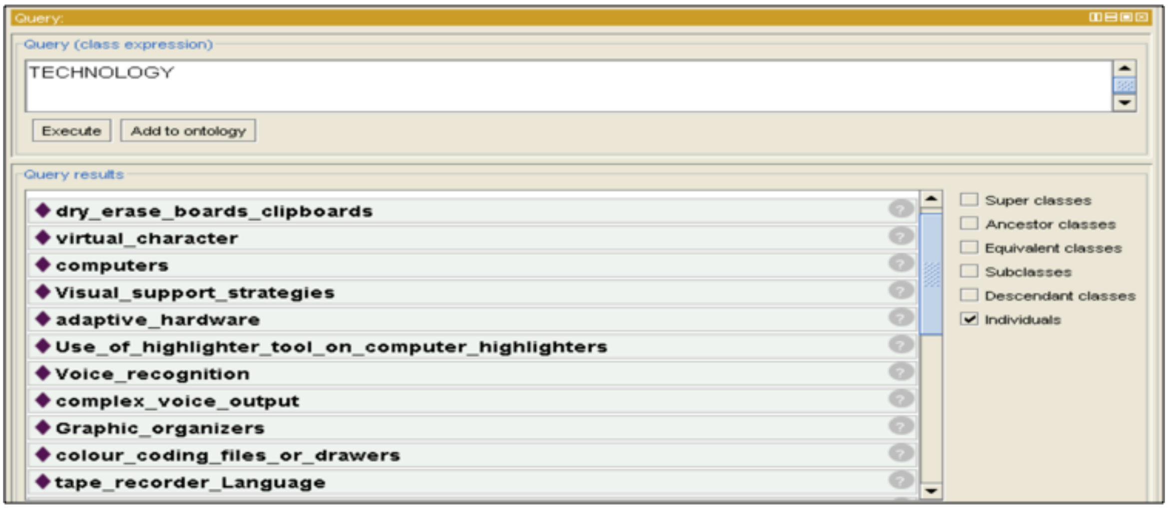


Fig. 5.10 Some of the individuals of TECHNOLOGY class

Similar to the previous procedure a specific JSF page will handle the user interaction once the third option is selected by user. A managed bean particular to this option handles user input and calls methods defined in OntologyManager.java class that works with the application ontology. The page user interacts with and shows the result of the user request is shown in Figure 5.11.

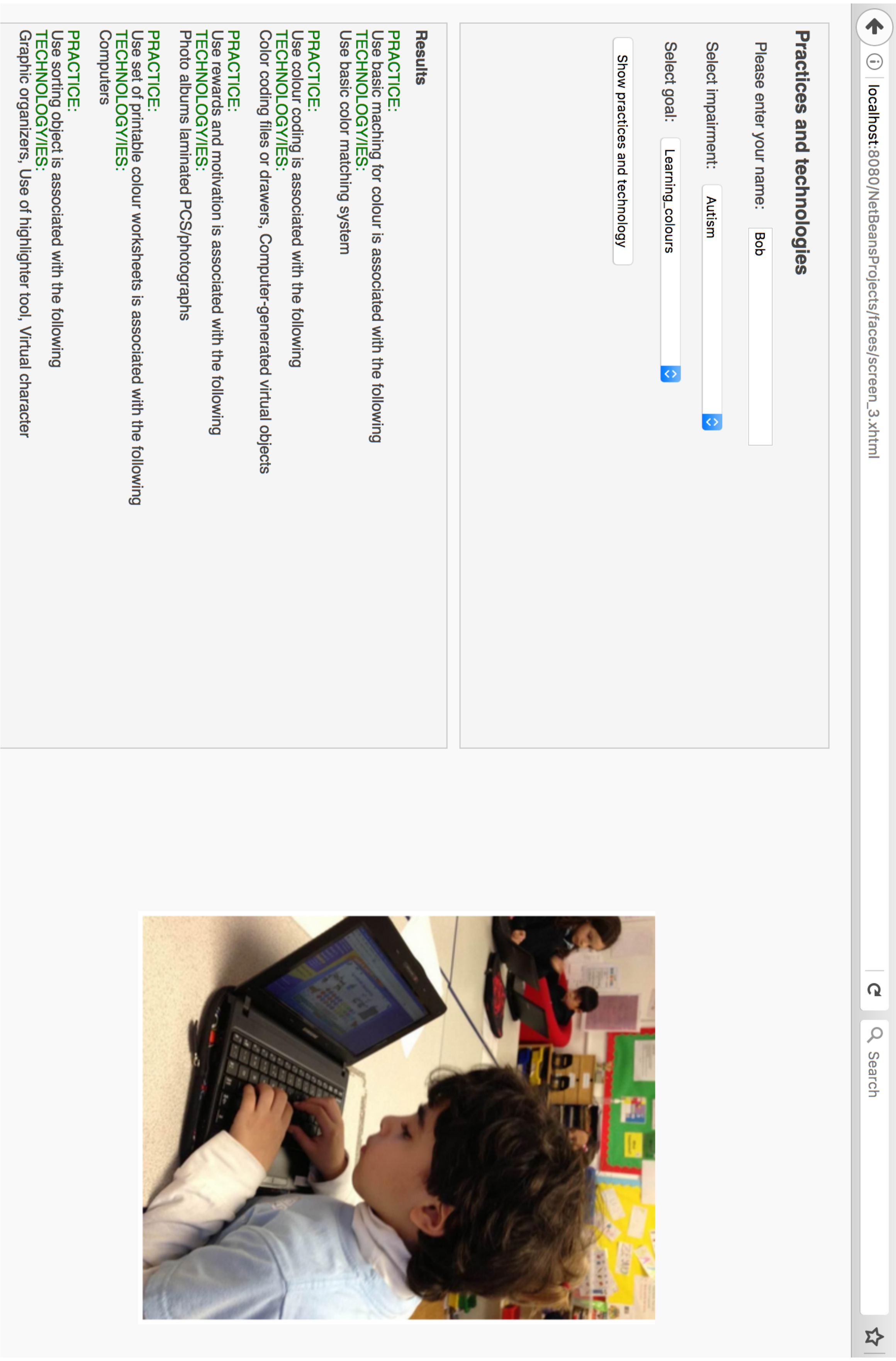


Fig. 5.11 The screen for the question "Which technologies will be associated with set of learning/teaching practices in your learning space?"

The indication of individual of *PERSON*, *IMPAIRMENT* and *GOAL* leads to insertion of the associated object properties shown figure 5.12.

$$\forall\, per(\text{PERSON}(per) \rightarrow \exists i\ (\text{IMPAIRMENT}(i) \land \text{has}\ per\ i))$$
$$\forall\, \text{per}(\text{PERSON}(\text{per}) \rightarrow \exists g\ (\text{GOAL}(g) \land \text{wishes\_to\_achieve}\ per\ g))$$
$$\forall\, p(\text{PRACTICE}(p) \rightarrow \exists i\ (\text{PERSON\_IMPAIRMENT}(i) \land \text{addresses}\ p\ i))$$
$$\forall\, p(\text{IMPAIRMENT\_PRACTICE}(p) \rightarrow \exists g\ (\text{GOAL}(g) \land \text{is\_for}\ p\ g))$$
$$\forall\, p(\text{GOAL\_PRACTICE}(p) \rightarrow \exists g\ (\text{TECHNOLOGY}(g) \land \text{exercised\_by}\ p\ g))$$

Fig. 5.12 Object Properties of Design 3 in DL Format

When the user clicks on Show practices and technology button, the result of the reasoning process, in this case practices and technologies, will be shown in the second box, as shown in Figure 5.9. The last SWRL rule run by the reasoning engine Pellet as explained in Chapter 4, Design 3 is: GOAL_PRACTICE(?gp) ∧ TECHNOLOGY (?t) ∧ exercised_by (?gp, ?t)-> GOAL_PRACTICE_TECHNOLOGY(?t)

5.4.2 Facilities For Administrators

The second box of the home page as shown in Figure 5.5 contains links for administrator to add a new class 5.13, to delete an existing one, to assert a new individual, or to add a new OP. The complete Java code of the application is attached, however an excerpt code for adding new class to the ontological model is copied below to show the core role of the *OntologyManager* class. The following extract is a method from the *OntologyManager* that is executed when the administrator wants to add a new class:

Listing 5.1 Ontology Manager Code

```
public static String createNewOwlClass(String className,
                                       String filePath,
                                       String ontologyBaseUri) {
  String result = "";
  OWLOntologyManager manager = OWLManager.createOWLOntologyManager();
  File initialFile = new File(filePath);
  try {
    org.semanticweb.owlapi.model.OWLOntology ontology =
      manager.loadOntologyFromOntologyDocument(initialFile);
    OWLDataFactory factory = manager.getOWLDataFactory();
    org.semanticweb.owlapi.model.OWLClass c =
      factory.getOWLClass(IRI.create(ontologyBaseUri + "\#" + className));
    OWLAxiom declareC = factory.getOWLDeclarationAxiom(c);
    manager.addAxiom(ontology, declareC);
```

```
      manager.saveOntology(ontology);
      result = "New␣OWL␣class␣" + className + "␣is␣added␣to␣the␣ontology␣" + filePath;
    } catch (OWLOntologyCreationException ex) {
      Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
    } catch (OWLOntologyStorageException ex) {
      Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
    }
    return result;
}
```

This method opens the current ontology, creates the new class axiom and adds it to the ontology creating a new ontology. The ontology is then saved to the OWL file on the local computer disk. The page allowing adding new classes to the ontology is shown in Figure 5.6. Inclusion of these feature facilitates modification of the ontological model without deep programming knowledge. This feature helps administrators to add new classes and object properties to the existing model should they wish to breakdown their categorization of concepts. For example, if they want to sort out different types of impairments under different categories they will be able to. That is to say, if they want, for example, group together all vision impairments separated from mobility impairments they can define two new classes as subclass of *IMPAIRMENT* class without too much difficulty.

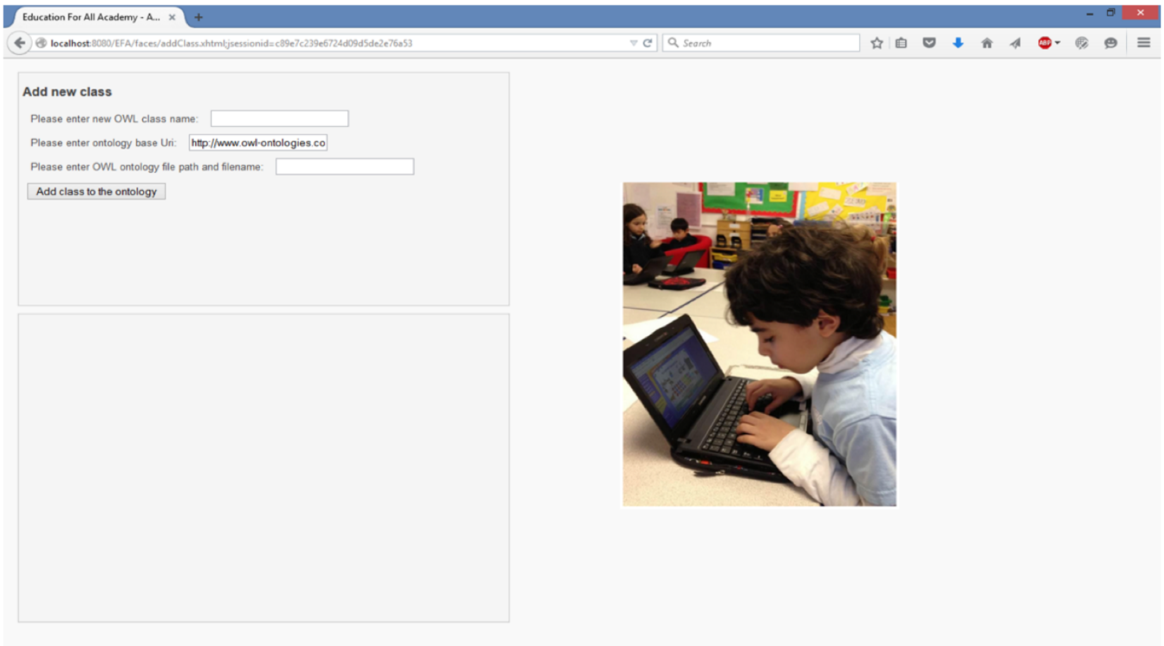


Fig. 5.13 Adding new class to the Ontology

Interface to delete a class, looks the same, only other method (*deleteOWLClass*) of the OntologyManager class is called. The method is similar to add method, only the remove axiom method is used to delete a class axiom: When adding individual, user enters individual name, class name, ontology base URI, and ontology path. Again the appropriate axiom is created and saved into ontology. Interface to add OP consists of OP name, its domain and range, ontology base URI and ontology path.

5.5 Technologies Used

5.5.1 Netbeans IDE 8.0.2

Netbeans IDE 8.0.2 (Oracle, 2012) is a free and open source IDE for users and developers and it supports various programming languages including Java. Eclipse and Netbeans are the most used IDEs for Java developing. NetBeans IDE enables the development of Java desktop, mobile, and web applications, as well as HTML5 applications with HTML, JavaScript, and CSS. It is also the official IDE of Java 8. It is well suited to develop quality Java web applications. Java programming language was chosen because it is flexible, it supports advanced web application development, it is multi-platform, and libraries exist to work with OWL ontologies. Glassfish Server 4.1 Java application server was used to deploy and run the web application (Oracle, 2012).

5.5.2 JavaServer

JavaServer Faces framework was chosen to develop this project. JavaServer Faces (Jendrock et al., 2014) is a server-side component framework for building Java technology–based web applications. Along with Spring MVC, it is the most used Java web framework. It consists of a component API and tag libraries. It is easy to create web pages, bind web components to server-side data, and wire components to backend application code. A typical JavaServer Faces application includes the following parts:

- set of web pages
- set of tags to add components to the web page
- set of lightweight managed beans that define properties and functions for UI components on a page
- web deployment descriptor

Optionally, it can also contain one or more application configuration resource files, a set of custom objects and a set of custom tags (Jendrock et al., 2014).

5.5.3 OWL API library

OWL API library (Hartel et al., 2005) (Horridge & Bechhofer, 2009) (Liu et al., 2010) (Horridge & Bechhofer, 2011) (Palmisano, 2011) (Knublauch et al., 2004) is a Java API and reference implementation for creating, manipulating and serialising OWL ontologies. In the OWL API, an *OWLOntology* is interfaced, modelling a set of logical and non-logical *OWLAxioms*. The central point of access is the *OWLOntologyManager*, which is used to load, create and access ontologies. The OWL API is open source and includes the following components: an API for OWL 2, RDF/XML parser and writer, OWL/XML parser and writer, reasoner interfaces for working with reasoners such as FaCT++, HermiT, Pellet and Racer. In this project, Pellet reasoner from OWL API library was used.

5.6 Summary

This chapter describes the successful creation of software application, using the proposed reference computational model ManSimLeS at its centre. High level software architecture was developed by using Java technologies, which have been carefully detailed above.

Our three competency questions gave crucial information about the types of impairment the learner has, the technologies they need and their learning goals. Java provide OWL Ontology Manager this will perform the processing and reasoning of information, the web based frontend was also enabling cross-platform usage of the application.

This information was tested in the EFA application and environment to reason. SWRL enabled OWL ontology was used, as can be seen in various situations within the scenario. Both the model chosen and the scenario are adaptable and practical enough to identify and meet the specific needs of any learner entering the LE.

Chapter 6

Conclusion

In this chapter current research is evaluated with respect to the objectives originally set in the first chapter, and an appraisal of the main contributions is provided. The problems encountered providing justification for necessary methodological improvements are critically explored. Next, a reflection on the modelling of the semantics and a discussion on the simplified ontological structure in comparison to the more complex ontological model, is provided with the aim to explain why the choice to simplify it was made. This is followed by reflection and evaluation on the departure from data type properties. The use of SWRL enabled OWL Ontology is additionally reviewed alongside a brief summary of the software architecture.

6.1 Evaluation of the Research

6.1.1 Limitations of the Study

There were a number of difficulties/limitations to face. Firstly, learning and applying semantic web technology was quite a challenge. However, the author has been developing skills in this area over the last five years, both through research, practice and contributing to international conferences and now feels more confident. As this technology evolves so quickly a difficulty is the need to engage with continuous professional development to keep these skills updated. Secondly, it was difficult to find enough learning practices in the reasoning process, to address learning/teaching practice. Thirdly, this objective is purely about collecting data, however it was not always easy to access information and only qualified data could be used. The aim was to find current, up to date information from schools, which in the future might be using this proposed computation model. However, this was a real obstacle, because the schools did not wish to take part because of reasons of ethics and confidentiality. Fourthly, time was a factor. As computing is such a rapidly growing area, it is difficult to keep up with the latest developments around the world, therefore the studies selected were not always as recent as desired.

In this research any solution to the problem stated above is looked at from a software engineering point of view. Introduction of the Sematic Web Technologies and opportunities it brought forward in processing semantics to infer further knowledge inspired this research to look into these technologies for any solution. To model the semantics of the teaching/learning environment this research uses OWL ontologies. SWRL rules are also used on top of OWL ontology to reason upon the existing knowledge to infer further semantics about the environment.

This research is aimed to produce a SWRL enabled OWL ontology upon which applications working in the environment are performed to provide services that users expect to receive. In this journey the thesis has gone through several experiences and classifications of the knowledge in designing the ontological model that express the semantics of the learning environment (Appendix A)(Appendix C)(Appendix D). Initially the focus was on using a large number of classes representing different concepts of the environment with characteristics presented by extensive use of data type properties. The lack of reusability of the model was its main drawback. In the follow up work the concentration was switched towards object properties rather than data type properties to improve the reusability of the model. In this approach several models with different design decisions have been made. With a minimum number of classes representing the concepts and object properties representing the relationship between them, research has managed to answer competency questions set to verify the model.

Further work in this area will be on the development of full scale software applications based on the reasoning mechanism proposed in this research, and how their performance can be optimised given the flexibility of the proposed model. Combining the domain and instructional module of the computational model with the learner module is another area the researcher should look into in the future.

6.1.2 Evaluation of Objectives

In this section the evaluation of the research is presented, by considering the three main objectives as these were set in Chapter 1 (section 1.4). To remind the reader, the objectives are summarised as follows:

(OB1) Put forward the requirement for individual learning needs with the aim to customise and direct support to individuals with needs of diverse range. This requirement dictates the management of the semantics of the LE and the configuration of the LeS so as to identify the needs of learners who exhibit a range of differences in learning, DiffInL.

(OB2) Cover a diverse range of impairments that exist among learners, also allowing personal preferences with suitable range and choice of options by providing a tailored learning space, as opposed to a generic plan. Coverage of all different types of disability/difficulty of learners and accordingly practices suitable for their impairments utilized is necessary in light of the technology and (OB1) above.

(OB3) Propose a reference model that secures the implementation of a LeS and implement a computational model that automates the configuration of the LeS and therefore is able to deal with main artefacts.

The accomplishment of the objectives during the course of the research has been reported in International Conferences, which include The Society for Design and Process Science (SDPS 2011-2015), The Saudi International Conference (SIC 2011) and The Saudi Students Conference (SSC 2015). The relevant references for each objective are provided in the corresponding section.

6.1.2.1 Evaluation of Objective 1

The main objective of this study has been to concentrate on the learning needs of the individual learner. As the needs of the individual are central, instructors have therefore not been targeted in the author's model, instead the focus has been on the learners. The expectation is that the individual learner's needs will be fulfilled as long as the instructor adjusts to its role. In this setting, in order for the system to work effectively, the instructor should have a variety of practices available.

The LE semantics as these are managed through the DMM (Section 4.3.1) and the full hierarchy of the ontological classes (figure 4.2) enable the learner to be set as the primary focus. In more detail, the hierarchies of the class PERSON $<$ PROFILE $<$ DISABILITIES and PERSON $<$ PREFERENCES $<$ PERSONAL_PREFERENCES explicitly model the individual's impairments and needs. The contents of the class reflect the same principle, for example as is shown in Table 4.4, for the class IMPAIRMENT, difficulty_with_change_in_routine was set, and for the class GOAL, learning_sequencing_and_order was set. Thus, the implemented ontology was modelled from the learner's perspective. Although a variety of models were employed, the starting point of each question has been the specific learning impairment spectrum and the goal of the learner. This focus is the basis of the ontological structure in all of the three designs, for example, in Design 2, Section 4.4.1.2:

(i) PERSON_IMPAIRMENT $\subseteq$ IMPAIRMENT and

(ii) GOAL_PRACTICE $\subseteq$ PRACTICE, GOAL_PRACTICE $\subseteq$ IMPAIRMENT_PRACTICE)

The focus on the learner's impairments and on the aimed learning goals is reflected also in the reasoning of the model. This is entirely learner-centered as it is evident when expressing the rules of reasoning in the SWRL Language. To use as example the Design 2, the condition is on the GOAL and the IMPAIRMENT_PRACTICE: GOAL(?g), IMPAIRMENT_PRACTICE(?ip), PERSON(?per), is_for(?ip, ?g), wishes_to_achieve (?per, ?g) -> GOAL_PRACTICE(?ip)

Objective 1 has therefore been accomplished; the management of the semantics of the LE and the configuration of the LeS allows customisation of the ontological model to the learner so that it can directly support individuals with a variety of impairments and needs. Further, the instructor is crucially supported by the system as in the case of learners with DiffInL, the specific needs are not always obvious; hidden and/or complex disabilities are frequent and consequently the process of tailored learning is not always addressed accurately (Section 2.2). The model used exactly manages to address this issue by enhancing the way educators meet the needs of the particular individual. The main results related to this part of the research have been published in (Almami & Juric, 2011a).

6.1.2.2 Evaluation of Objective 2

As Objective 2 requires, the structure of the ontology allows a dynamic and, in theory, unlimited coverage of all possible impairments, personal preferences, and technologies. The ontological concepts and their hierarchies, as these are contained in the Learning Space Model Module (LeSMM) extracted from the DMM, are sufficient to describe any situation that might be encountered in LEs. The OWL/SWRL technology provides an efficient and flexible platform for managing the Semantics and reasoning upon Domain Concept (figure 4.1). Objective 2 has been achieved through a combination of OWL/SWRL and the individuals.

The class hierarchies are extracted from the DMM and are contained in T-Box T along with the set of axioms about the concepts and relationships between them. The possible individuals that are members of some concept are contained in A-Box A . This allows the description of a large range of possibilities for each concept. In Table 4.4 instances of possible individuals for the core classes are shown. Although only for demonstration, it is clear that, in principle, unlimited range of impairments, goals, practices, and technologies is attainable. The content of these concepts is used for the reasoning process. To demonstrate how this is done the author of the project implements Design 3 (Section 4.4.1.3). The ontology of

Design 3 which provides the foundation for the reasoning mechanism is shown in Figure 5.2. The reader is reminded of the foundation set:

$C\Delta$ = {PERSON, IMPAIRMENT, PRACTICE, GOAL, TECHNOLOGY } (Section 4.4.1). Based on these main classes, the necessary subclasses for efficient reasoning process are defined (Table 4-2). The range of all possible impairments corresponding to one student is considered in the class PERSON_IMPAIRMENT which is a sub-class of the class IMPAIREMENT. The latter contains all possible impairments. Similarly, for practices, the corresponding practices of a specific impairment are stored in the class IMPAIREMENT_PRACTICE. This is a sub-class of the class PRACTICE which contains all possible practices. The practices appropriate for the specific goal (and impairment) are contained in the class GOAL_PRACTICE, which is again a sub-class of the class IMPAIRMENT_PRACTICE. For the technology, the subclass GOAL_PRACTICE_TECHONOLOGY suggests the appropriate technology. Thus, the OWL provides the means to represent all possible ranges of impairments and personal preferences. By running the reasoning mechanism on these (Figure 4-8), the practices suitable for the selected goal and student as well as the corresponding technology are returned by the system (Section 4.4.1.3). The SWRL rules are the ones that allow this process. The alternative implementations are described in Sections (4.4.1.1 and 4.4.1.2).

With the sufficient representation of the fundamental concepts in OWL and with the reasoning rules of the SWRL, each instance of the ontological model answers a specific competency question. For the three types of questions that are provided to the user in the proof of concept demonstration of the model, three distinct SWRL rules were implemented. It is clear that there is no specific limit on the amount of supplementary SWRL rules that can be included, and/or on their degree of complexity.

As is shown in the paragraphs above, the requirements of Objective 2 have been successfully met since all possible impairments and personal preferences can be represented in the system, and a tailored learning method and technology is provided directly to the user.

N.B. The main results related to this objective have been published in (Almami, 2012).

6.1.2.3 Evaluation of Objective 3

The proposed reference model (Figure 4.1), as demonstrated, secures the implementation of a LeS, and a computational model (ManSemLeS in Section 4.3) that automates the configuration of the LeS.

The reference computational model proposed by the thesis author constitutes a departure from previous models in terms of efficiency and flexibility.

The OWL technology is used for computations and not for creating an expert system. This system will definitely secure the configuration of the LeS without the need for constant checking. The model has been successfully tested Sections 5.2 and 5.3).

An important distinction is necessary at this point. The reference and computational models work independently of the actual data stored in the system. The set of stored data defines a specific implementation. To demonstrate the applicability of this method a minimum LeS needs to be configured and the model needs to be provided with some sample data (individuals). This was sufficient in order to show that the system works in principle (Almami et al., 2013) (Almami, Juric & Ahmed, 2014). However, the reference and computational models are there and able to function for a multiplicity of scenarios. The success and full potential of an implementation in real life relies though, not only on a valid reference and computational model, but also on the amount and suitability of stored data.

Also, it is recognised that the model is not necessarily able to address every situation, as it is impossible to foresee future challenging and complex situations.

An implementation with limited practices, for instance, will not provide learning solutions in a large number of situations. If the returned number of practices in a given query through the SWRL is zero, this does not invalidate the reference model. On the contrary, this case should be seen as a useful indication concerning the specific implementation of the LeS and is considered useful, as it highlights areas for improvement in the invented practices. The main results related to this objective have been published in (Almami, Juric & Zaki Ahmed, 2015).

6.2 A Reflection on the Objectives

As Objective 1 requires, the learner is the centre of our approach. While for the configuration of the LeS, it is necessary to allow the users to express their needs and expectations, with the use of appropriate interfaces; the focus is on the learner and not on the instructors. This differs from the author's earlier publications in SDPS 2013, (Almami et al., 2013) and also SSC 2015 (Almami, Juric & Zaki Ahmed, 2015). In both of these papers the focus had been on both the learner and the instructor.

In the 2016 computational model, the focus has changed and the aim is not to provide a tool for both. The instructors are still involved since they can input practices as a means of improving knowledge. However, the system is built to facilitate the learner and not to suggest practices to the instructor who in turn will impose them to the student. It is important to stress that the practices are not imposed but are suggested. Certain practices can be very generic (e.g. learning colour through shapes), and thus it would be inappropriate for them to be imposed when an impairment is incompatible with them (e.g. colour blind child). The study recognizes that the needs of both the learner and the instructor need to be met. Although the focus is the learner, it is impossible to deliver the goal of personalized learning if the needs of the instructors are not delivered as well. For the system to work effectively it is crucial for the instructors to have a variety of teaching practices available.

The instructor, apart from setting goals, can be provided with suggested solutions, when these are not handy. These can rely on the previously recorded student's personal preferences. Since in the most common scenario the instructor is responsible for a class of students of mixed abilities, the per-student solutions suggested by the system are crucial for individualised learning. This way the instructor is able to adjust the methods, and thus put differentiation into practice more easily. Apart from the suggested solutions, the instructor is also given the option to modify the range of possible ones.

It is therefore shown that the design allows the accomplishment of the learning goals keeping the focus on both the individual and their specific impairments. At the same time, it acknowledges the role of the instructor in identifying the impairments but also in setting the goals. However, the instructor's existence is not a requirement for a successful learning process. The instructor's role of retrieving practices is replaced by the system. In a variety of situations, the instructor can only act as system manager and the student can follow the steps independently. Both can be involved in the learning process, but with their own distinct roles. The student needs to participate in a particular learning session, express the personalised profile as learner, and articulate any DiffInL. The instructor, on the other hand, needs to design the instructions of a learning process together with the appropriate sources/materials, and ultimately assess the learner's performance and the learning outcomes.

6.3 Summary of the Contributions of Current Research

The evidence presented in this thesis shows that LD students have traditionally been overlooked within an educational system which relies heavily on a sequential and logical method of delivery (Section 2.1). This is disadvantageous to the LDif student because they process information in a completely different way. They are generally visual, holistic, big-picture learners, who require context and connectives to be able to understand instructions clearly, and to follow an exercise more easily.

These differences lead to a disability divide. While LD students have many abilities and are often of average or above average intelligence, they do not receive validation for their skills within a restrictive and rigid educational system which ignores their needs.

An educational system which embraces equality and diversity requires constant review, analysis and improvement of practices to ensure empowerment of our most vulnerable students. The research conducted by the author of this thesis has been directed towards this aim by attempting to redress the balance and shift the fulcrum of the disability divide to serve the needs of LD student. LD learners are excluded from technology that would allow them to access online web information, particularly in Higher Education, where there is currently a lack of sufficient reasonable adjustments (Hollier, 2007) see Section 2.6. In response to this dilemma this new 2016 computation model has opened up online web learning possibilities for LD learners which will suit their unique learning styles and enhance their educational and life chances.

Modern technologies offer powerful mechanisms for simulating a real world classroom and for enhancing students' experiences. Therefore, learning environments can be significantly benefited. This omission has been the core of current research which makes use of the ubiquity of new technology, combined with designing a practical generic solution to greatly enhance the educational learning experience for LD students. Since LDs are not equal in their needs, this is crucial in order to allow them to be included in the main stream education providing appropriate educational materials and addressing their individual learning needs and goals and thus supporting them in realising their full potential. The project author first highlights the problem mentioned above, and then provides the analysis and methodology that allows the implementation in practice of educational tools that cover this gap.

This piece of research has led to three main contributions.

- **Firstly**, a new computational model that addresses the needs of people with difficulties in learning has been provided and it has been shown how this can be used to configure an LeS.
- **Secondly**, a corresponding novel and re-usable reasoning mechanism implemented in OWL and SWRL computational environments has been provided. Therefore, a unified way for exploiting the semantics from our computational environments has been proposed, in terms of OWL classes, constraints, and their mapping for configuring any LeS.
- **Thirdly**, it has been demonstrated that the results can be integrated with disciplines such as psychology, sociology, human-computer interactions, digital design and multimedia for the implementation of the computational model.
- **Additionally**, an efficient software solution has been offered which is optimal with respect to the amount of interaction required from the user. This has been achieved

by keeping the number of ontological concepts to a minimum, and by switching to object properties as a dominant factor besides classes. Thus preparation of the teaching environment is not demanding in terms of time and effort.

6.4 Critique on the Research

In order to be analytical, the history of learning disability, (Section 2.1), and the relative current scientific literature (Section 3.3, 3.4 and 3.5) were thoroughly examined at the outset. This was considered necessary in order to appreciate the aspects of learning disabilities in educational environments and its distinctive characteristics. Thus, an early definition of learning disability was provided, dating back to the 1960s. This definition was debated at the time, a fact that indicates the lack of universal agreement on the characteristics of learning disabilities.

Semantics were then considered, and this exploration highlighted the distinction which exists between LD and LDif. (Section 2.2) This consideration led the author of this thesis to conclude that differences in learning (DiffInL) is a more suitable term for addressing a spectrum of learners described at present in cognitive and behavioural psychology.

Since, technologies are crucial in supporting education, an insight of their impact on addressing LDif and DiffInL was provided, followed by an overview of VLEs and their inefficiencies with respect to the needs of modern learners in general (Section 2.4.2.1).

In Chapter 3 the research problem was presented by analysing the existing literature and identifying areas which were not covered. Problems that DifflnL students faced, when accessing online technologies, were also explored, as were the currently offered semantic web technologies that attempt to solve these problems, together with a number of limitations which are detailed in Chapter 3.

In Chapter 4 the chosen approach for managing the semantics of a particular LeS in order to accommodate learners with dyslexia and attention deficiency disorder was outlined, (See Section 4.3.1.1 and the conference paper by (Almami & Juric, 2011).

The initiative of the project's author, as described in the Background Section (Chapter 2), has been to treat any instance of VLE as a pervasive computational space. Semantic web technology and OWL/SWRL enabled ontologies in particular have been used, in order to understand, model and create VLEs, which in turn guarantee participation of students with disabilities. Consequently, a demonstration was produced by answering sample competency questions which deal with a fraction of requirements of such VLEs. These questions are based on the same set of semantics, initially defined within an existing VLE ontology, and all follow the same procedures to provide a response.

The aim of chapter 5 was to prove our concept through creating a software application with the proposed computational model at its heart, and then test this out with several trial groups of DifflnL students. This proved that the model was different to software engineering (SE), since whereas they are accumulating knowledge, the system proposed by the author of this project, using SWRL enabled OWL ontology solution does not accumulate knowledge.

The system also allows the administrator to add a new class, to delete an existing one, to assert a new individual or to add a new OP. This flexibility facilitates modification of the ontological model without technical knowledge of the precise implementation. Consequently, it is possible for a user of the system to manage the impairments and their categorization so as to accommodate for specific and varying requirements. It is further possible to manage the range of practices and technologies to widen the possible solutions. Therefore, this option highly increases the efficiency of the system, as it serves at the same time as a convenient tool for the dynamic storage and organisation of available practices and technologies, taking advantage of the accumulated experience of the instructors.

Flexibility is greatly increased and innovative in this system, as it addresses the needs of the instructor as well as those of the student, which is important for achieving high quality personalised learning. Thus, all possible situations can be accommodated: from a physical and traditional classroom, to a purely virtual LeS, all configured according to the users' needs and expectations.

For the application of the proposed computational model (Section 5.2), a scenario was created in Section 5.1.1. This scenario was called the Education For all Academy (EFA), set in a secondary institution. A number of different students were described, in terms of their impairment and their learning goal. Following this, the software architecture was described in detail, in Section 5.3, using OWL API, for representing the user interface component, JavaServer Pages (JSP), for expressing UI components within a JSP page, JavaBeans components were used to encapsulate the data and application-specific functionality of the components. The Web application was built using NetBeans, JSP technology. Also, a set of backing beans were used which are JavaBeans components which define properties and functions for GUI components on a page. Backing beans are all our classes in EFA (See Section 5.3).

The technologies which enable us to create a software application from the proposed model (Net Beans IDE, Servlet technology, OWL-API, Jess Engine, Protégé ontological editing tool, all running on a Cloud) are there and helped us to prove that our ideas, interwoven in the computational model, can work. However its real life deployment depends on how clearly we can define what DiffInL in education are and how we wish to deploy learning theories when addressing them. There is no consensus on both in our wider education communities. This work might trigger discussions on raising awareness of both: the power of technologies when creating personalized spaces in modern LE, where we must address DiffInL and the problem of modernization of traditional learning theories, which have not been properly reviewed since the 90s.

With reference to the two main parts of the Proposed Reference Model for configuring the LeS (Section 4.3), namely the MODEL components, and the MANAGEMENT components, the author of this thesis presents the following points of critique and further suggestions for modification.

Firstly, GUI-APPLICATION. Although the implementation of the model was presented as a proof of concept, it is still usable in real scenarios. Taking into account that DiffInL students would most likely face difficulties in their interaction with the system because of their disabilities, a meaningful area of improvement is the ease of use of such an interface. A more visually compelling interface as well as the incorporation of touch features with tactile or audio feedback would substantially improve the user experience. Additionally, providing access through mobile devices, which students most likely use for other activities, will make the management of the learning process more familiar to them.

The MODEL components have been chosen to achieve the particular objectives, as described in Section 6.1. However, the same theoretical framework as is provided allows modifications of the current design. Perhaps there is room for improvement, and this could be exploited in the future by:

- introducing a small number of extensions in order to include added features for the same purposes of the current research (assisting DiffInL students), or
- modifying the semantics of the ontology in order to extend the range of applicability

The first option would allow features such as evaluation of the learning from the instructor, or even student's self-evaluation. The second option suggests an unlimited range of potential applications. The same principles employed in this model could be applied, for example, in automated medical diagnosis, based on symptoms and patient history, or, automated meal recommendations based on particular health conditions and personal preferences.

The MANAGEMENT components manage the semantic stored in various models in order to carry out the configuration of a LeS. At the moment the OWL/SWRL model provides the best available solution, however, in the light of forthcoming technologies or upgraded versions of the current, the author would consider suitable updates in the implementation in order to take advantage of added features and functionalities.

6.4.1 Reflection on the Modelling of LE Semantics

In order to model LE semantics, the author of this project recognised the importance of building in to the framework, constant reviews and evaluations, to give the opportunity for adequate reflection. The in-built reviews gave an opportunity for checking how effective the ontology was, and the chance to be honest about limitations, and then to trouble-shoot them, so that possible solutions could be considered, and any necessary modifications made.

Part of the review process involved the author creating and testing the ontological model through two separate case studies. This involved experimenting with two trial groups of DifflnL students, and then publishing the results in two papers, (Almami & Juric, 2011) and (Almami & Juric, 2011).

At the beginning a state of the art, large ontology was used with data-type property. In this research three reference computational models were produced, the first one was a conference paper published in 2013, (Almami et al., 2013). After reflection, this model was then modified in 2014. The latest computational model is the one which was introduced in Chapter 4, (Section 4.3) of this study. In the following sections, reflection and modifications are shown in a step-by-step explanation. To check that the research objectives had been met, the author of this project will cross-reference the initial objectives.

6.4.1.1 Reflection on the Proposed Reference Computational Model

Over time, the reference computational model has evolved, due to considerations made after testing, and when problems were perceived. The initial model in 2013 contained multiple learners, and multiple instructors see Figure 6.1 below.

Figure 6.1 Shows the basic ontological model, which stores semantics of LEs. Our choice of basic ontological classes, originating from a consideration of multiple learners and multiple instructors.

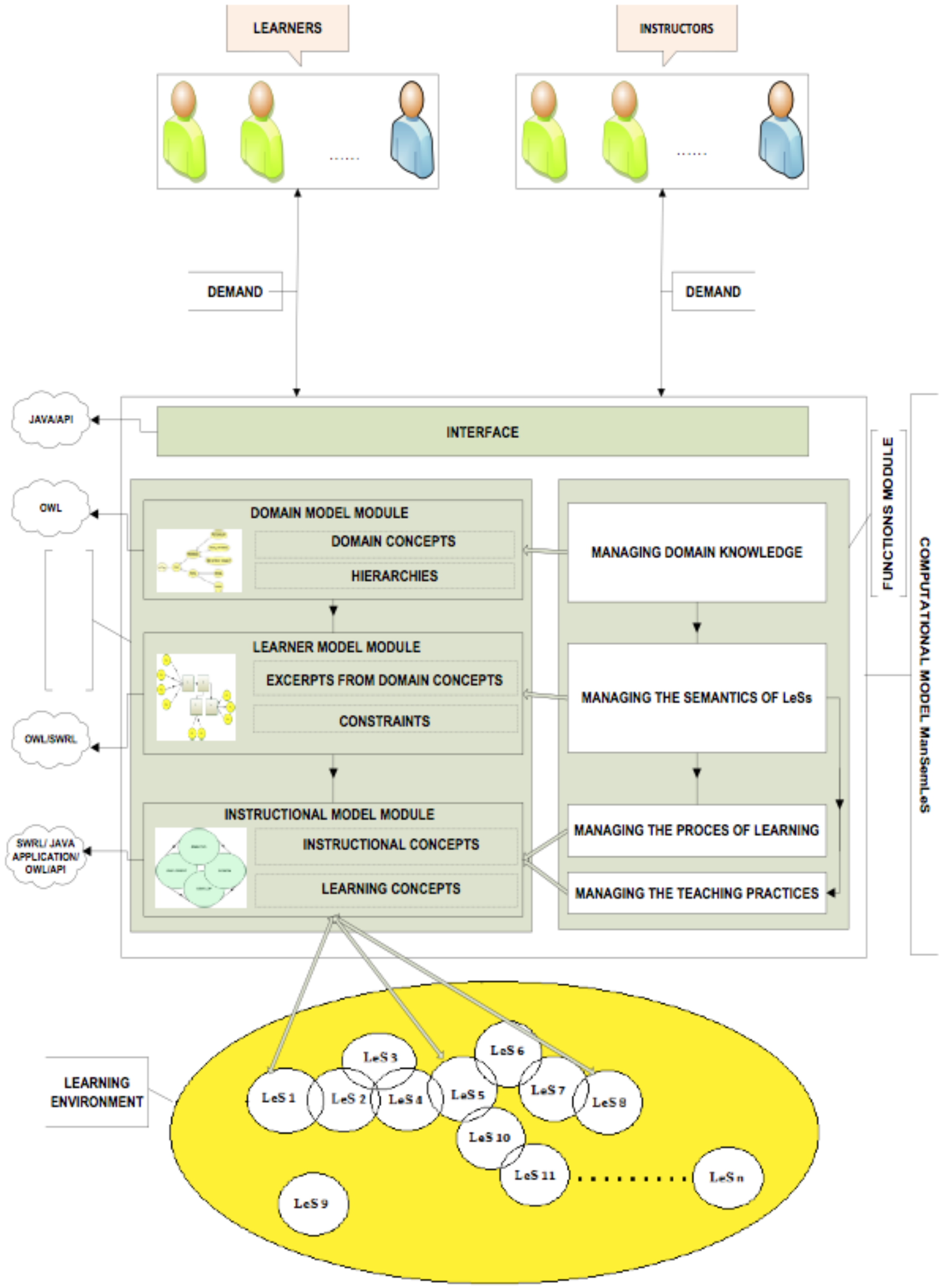


Fig. 6.1 The Reference Model (Almami et al., 2013)

This was then revised in 2015 see Figure 6.2, when it was changed to a single user learner/instractor and a single instructor (Almami, Juric & Zaki Ahmed, 2015). Again, after evaluation (described in Chapter 4 of this research), it was revised further so that there was just one user LEARNERE/INSTRUCTORS and the instructor was removed Figure 4-1 (section 4.3).

The reason for this final modification has been that the reference model is geared towards the student, who learns, and who is not concerned with how the instructor feels. The learner is pivotal.

The conclusion drawn in the evaluation was that the student and the instructor are not equal, even though they are both involved in the process. Taking this into account therefore, on reflection, a decision was made to remove the instructor. After removing the instructor as a user, a decision was made to put forward the learner. However, without delivering through practices the learner would not achieve the goal. So, the need for an instructor was recognized, but in a revised setting where the concern was not about what the instructor would like to teach, but on what the learner needs. This has been the starting point and all the competency questions were written with that in mind.

In summary, on reflection, objective 1 (OB1) has been achieved, by filling the ontology from background research, using both domain concepts and individuals of domain concepts. This objective was achieved in the ontological model and the question of the individual learner's needs, and their specific impairments has been constantly addressed (See Chapter 4, section 4.3).

In addition to the above reflection, which describes how the original model has been refined and improved, the author has further evaluated in depth the use of SWRL enabled OWL Ontology, within the two separate papers mentioned above, in great detail. For further information, please refer to the following references:

- (Almami et al., 2013)
- (Almami, Juric & Zaki Ahmed, 2015)
- Chapter 4 Section 4.3

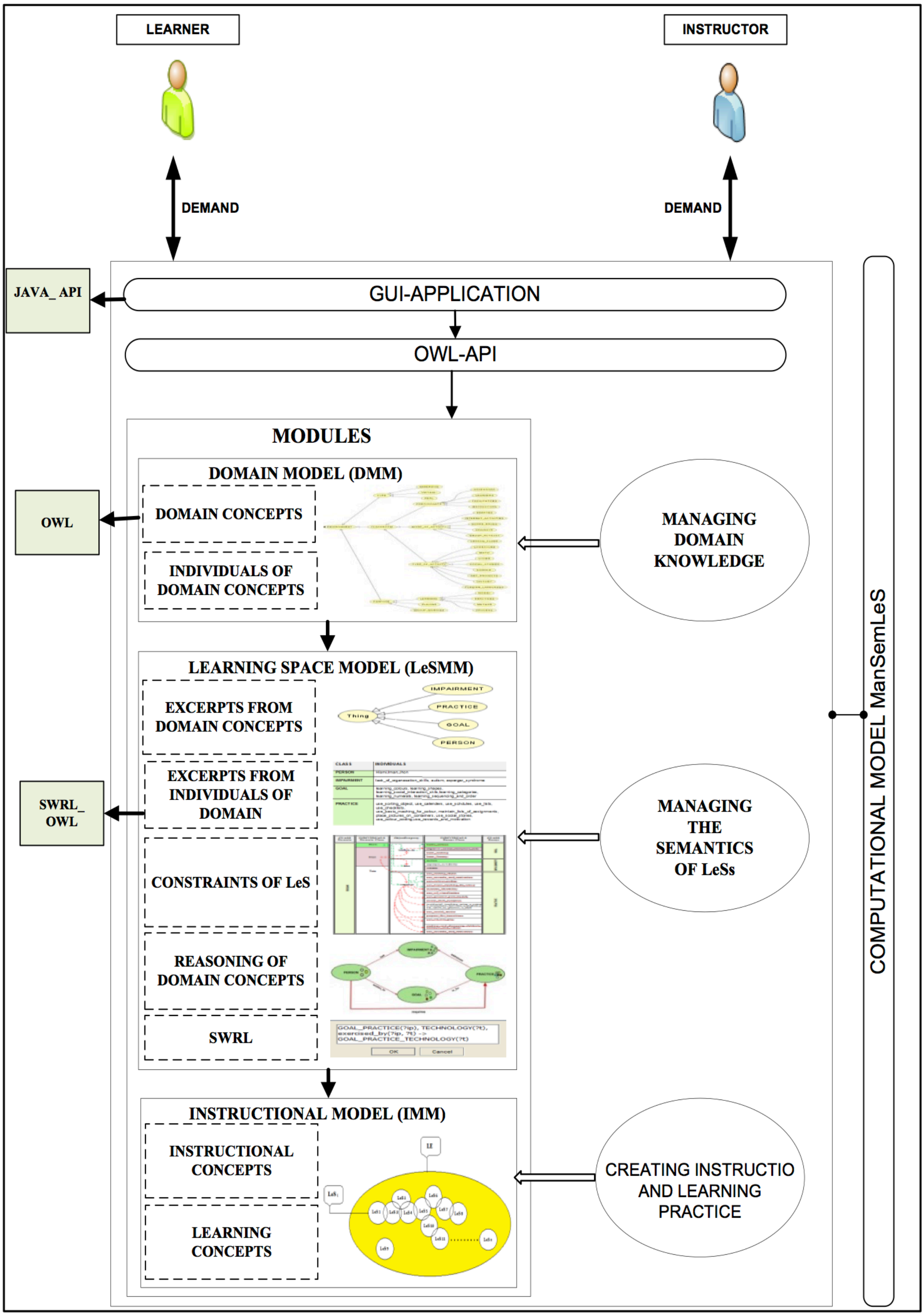


Fig. 6.2 The Reference Model for Creating LeS (Almami et al., 2015)

6.4.1.2 Situation-Specific Structure Versus Complex Ontological Model

The first approach for modelling the LE Semantics focused on a state of the art ontology, (Almami & Juric, 2011) see Figure 4.4 (section 4.3) (Appendix A).

The aim was to fully capture a wide range of concepts and represent the majority of notions and relationships appearing in a LE. Therefore, the corresponding ontology was characterised by significant size and complexity. While this reflects a reasonable aim for an extended line of research, in the context of a PhD project, after reflection, it was considered preferable to follow a more realistic approach and concentrate on a situation-specific ontology, derived from the big, complex ontology.

When the practice was evaluated, the first problem encountered was that there were too many classes see Figure 4.4 in chapter 4 (section 4.3.1).

6.4.1.3 Moving Away from Data Type Properties

After further reflection and testing, which is documented in the paper entitled ”OWL/SWRL Enabled Ontologies for Managing the Semantics of VLEs Customised for Students with Disabilities” (Almami & Juric, 2011) , it was recognised that broad use of data properties in ontological classes reduces the reusability of classes and the ontology. In response to this issue, a different structure was introduced with object properties instead of data properties being dominant. When data properties are used, the emphasis of the model is on individuals of classes (Almami & Juric, 2011), but when the attention is more towards the relationships between individuals of classes then data type properties should give way to object properties. On that basis, the number of classes and subclasses was reduced, otherwise the representation of the learning space would be impossible because our solution is a moment in learning and the next moment is different!(See Sections 4.4.1.1, 4.4.1.2 and 4.4.1.3).

Evaluating the model showed that if the number of classes had not been reduced, then it would have negatively impacted the end result, i.e. users would have to input a large amount of data through an elaborate process which would call for a prohibiting duration of time to start off the system. Testing resulted in a breakthrough, because it changed the focus to attention to OP, with less ontological classes and yet it did not sacrifice the necessary data (see Section 4.3.1.1.).

We have used in our earlier experience (Almami & Juric, 2011a) data properties in defining classes. Considering the fact that broad use of data properties in ontological classes minimises the reusability of the classes and the ontology, we have tried a different structure whereby object properties and not data properties are dominant. When data properties are used, the emphasis of the model is on individuals of classes (Almami & Juric, 2011a), but when the attention is more towards the relationships between individuals of classes then data type properties should give way to object properties. On that basis, the number of classes and subclasses was reduced.

6.5 Contribution

This research attempts to undertake an interdisciplinary research which spans software engineering, education, cognitive science and pervasive technologies. The technologies which enable us to create a software application from the proposed model have helped us to prove that the research proposal can work. However, its real life deployment depends on how clearly we can define what learning differences in education are and how we wish to deploy learning theories when addressing them.

There are no related works which use OWL and SWRL in order to make decisions on teaching and learning practices and assistive technologies in classrooms which accommodate students with learning difficulties Figure 5.11.

The proposed reference computational model ManSemLeS was tested in the EFA application Figure 5.6and environment to reason. The computational model represents the semantics of the situation, inferring new knowledge and reason upon selected class is accurate Figure 5.6. A number of situations in the EFA scenario evidence the use of SWRL enabled OWL ontology. See (section 5.5.1) in chapter 5. The study contributes three different ontological model designs which are sufficiently flexible to identify and meet learner's specific needs in the LE.

By connecting the semantics of learners' learning differences, preferences and goals with the characteristics and purposes of the learning space and services delivered within them, we are able to open doors to any possible combination of learner's preferences and needs in terms of their learning differences with the purpose of a particular space, its materials, teaching and learning practices and expectations from the learning space.

Thus, an effective contribution to the gap in existing knowledge and technology has been addressed through the proposed ManSemLeS and this improves reasoning processes and inference, providing a workable and practical solution.

6.6 Conclusion of the Research

This research shows that applications can be created based upon SWRL reasoning, and OWL ontologies can be used for performing software engineering tasks outside the SWT. The computations with SWRL shows how the dynamics of such applications addresses constant changes in the environments where it is run and how these changes are addressed through OWL concepts and SWRL reasoning. We show that OWL model can be constantly "tuned" according to the questions we may ask in such environments.

For demonstrating the functionality of such applications we use the education domain, we focus on the problem of teaching and learning practices for students with impairments who could like to achieve certain learning goals. The dynamics of these types of application is integrated in the way we compute with SWRL: we sometimes move individuals in OWL as a result of reasoning and sometimes infer constraints as the result of running SWRL. We demonstrate that the building of such applications is feasible and it remains to be seen how this can be used in commercial applications.

We propose that the VLE, and the reference computational model which has been designed, achieved by using SWT, offers educators the opportunity of empowering DiffInL students. The reference computation model created is a new departure, which will change and improve the learning experience for DiffInL students, giving them increased independence, more choices, and a range of materials which are highly interactive, exciting, fun and multi-sensory. At every stage of the process the voice, choice, abilities, learning style preference and unique skill set of the DiffInL student has been central, with the aim of making a contribution a future where every learner, even the most vulnerable, will be valued, and better placed to achieve their potential

All the initial objectives have been successfully met and we consider that a valuable contribution has been made through this research.

6.7 Future Works

The aim of the researcher in the near future is to enhance the existing reference computational model and extend it by creating apps for smart phones, ipads, personal computers and classrooms. To give learners more independence, and allow them to extend their studies outside of the classroom, to the home, I would like to design a tablet using the mechanism of this project. Studies show that DifflnL students learn better when using multi-sensory materials, therefore smart phones, tablets, etc. which run apps would make this model much more accessible. The author of this project looks forward to contributing to a rapidly developing technological debate, through which the LE can be transformed into a personalised, flexible, interactive space. This will go some way to address the difficulties of modernising out-dated learning theories and practice, which have not been adequately reviewed since the 1990s.

In terms of future research activities which are complementary, there are a number of areas of interest:

- One aim would be to build bridges with as large a number as possible of educational providers, from Early Years Education right through to Higher Education. The purpose of this would be to run training workshops for IT specialists as part of their Continuous Professional Development, so that they could learn about the enormous potential of this reference computation model and help to implement it.
- Another aim would be to contribute to learning materials. This could be achieved by encouraging specialists in Specific Learning Difficulties to work together with instructors to create a range of materials which are tailored to the needs of DiffInL students.
- The dynamic interaction can be further developed so that during a session, based on feedback from instructor and learner the practice can be modified to produce a unique personalised experience.
- Continuing this research, and getting it into the LE will have obvious economic implications, therefore costing and commercialisation should be explored.
- Another proposal is to approach appropriate IT firms to discuss how best to move this forward and to test out whether there would be possible investors, given that they would get profits from circulating the software.
- Also an investigation would be made to government funding bodies to see what is available under the Education and Disability budgets. Although it is acknowledged that there have been a number of recent cuts to disability funding over the last year, the labour party's intention to appoint a Shadow Minister for Neurodiversity is very hopeful, and provides a degree of optimism for learners who process differently, and for educators and researches in the field.

In the future, the project author main aim is to continue to make a contribution to the existing knowledge and publications on the use of OWL-API for software application, liaising with other researchers in the field, evaluating systems, writing papers and promoting best practice.

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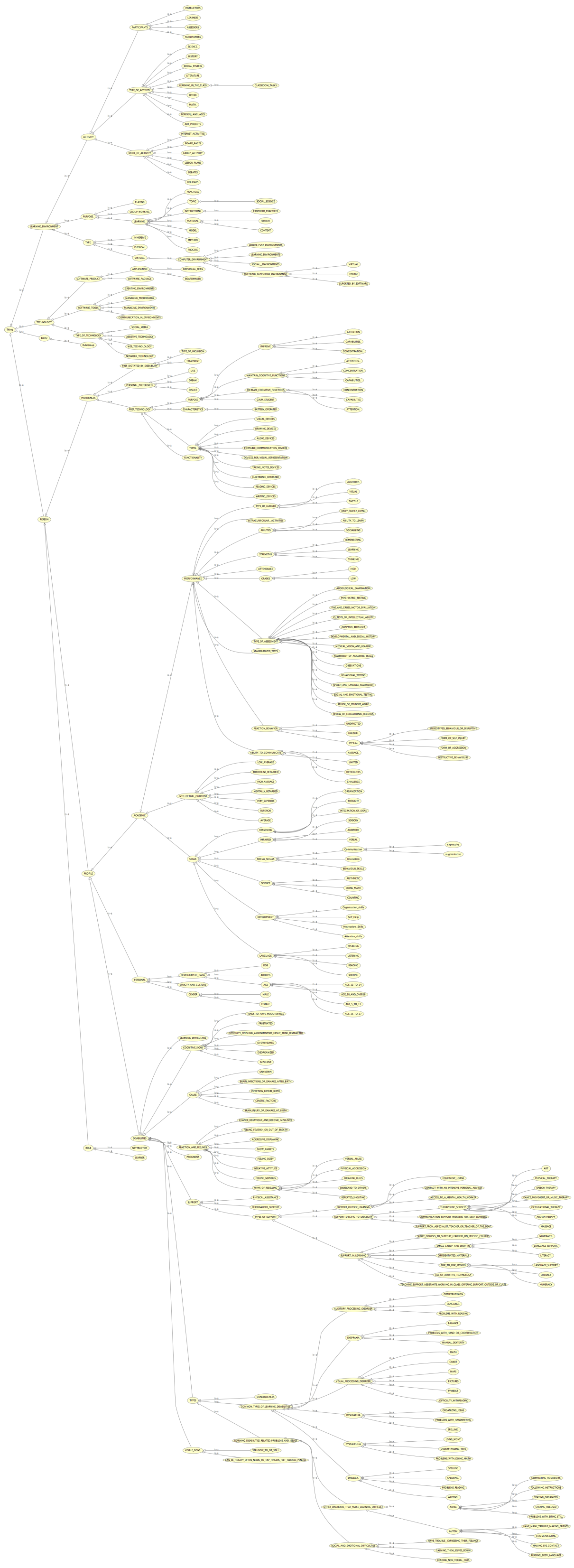
Appendix A

Current Ontological Classes for LE



Appendix B

The software application

```
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package efa;

import com.clarkparsia.pellet.owlapiv3.PelletReasonerFactory;
import java.io.FileInputStream;
import java.io.FileNotFoundException;
import java.io.FileReader;
import java.io.IOException;
import java.util.ArrayList;
import java.util.Collection;
import java.util.Iterator;
import java.util.List;

import com.hp.hpl.jena.ontology.OntModel;
import com.hp.hpl.jena.reasoner.Reasoner;
import com.hp.hpl.jena.util.FileUtils;

import edu.stanford.smi.protege.exception.OntologyLoadException;
import edu.stanford.smi.protegex.owl.ProtegeOWL;
import edu.stanford.smi.protegex.owl.jena.Jena;
import edu.stanford.smi.protegex.owl.jena.JenaOWLModel;
import edu.stanford.smi.protegex.owl.model.OWLClass;
import edu.stanford.smi.protegex.owl.model.OWLIndividual;
import edu.stanford.smi.protegex.owl.model.OWLModel;
import edu.stanford.smi.protegex.owl.model.OWLNamedClass;
import edu.stanford.smi.protegex.owl.model.OWLObjectProperty;
import edu.stanford.smi.protegex.owl.model.OWLOntology;
import edu.stanford.smi.protegex.owl.model.RDFIndividual;
import edu.stanford.smi.protegex.owl.model.RDFProperty;
import edu.stanford.smi.protegex.owl.model.RDFSNamedClass;
import edu.stanford.smi.protegex.owl.model.impl.DefaultRDFSNamedClass;
import java.io.File;
import java.io.InputStream;
import java.util.LinkedHashMap;
import java.util.Map;
import java.util.logging.Level;
import java.util.logging.Logger;
import org.semanticweb.owlapi.apibinding.OWLManager;
import org.semanticweb.owlapi.io.OWLObjectRenderer;
import org.semanticweb.owlapi.model.OWLNamedIndividual;
import org.semanticweb.owlapi.model.OWLOntologyCreationException;
import org.semanticweb.owlapi.model.OWLOntologyManager;
import org.semanticweb.owlapi.reasoner.OWLReasoner;
import org.semanticweb.owlapi.reasoner.OWLReasonerFactory;
import org.semanticweb.owlapi.vocab.PrefixOWLOntologyFormat;
import uk.ac.manchester.cs.owlapi.dlsyntax.DLSyntaxObjectRenderer;
```

```java
/**
 *
 * @author Darko Androcec
 */
public class OntologyManager {
  /* Jena OWL model */

  JenaOWLModel model;
  private static OWLObjectRenderer renderer = new DLSyntaxObjectRenderer();

  public static void main(String[] args) {
    getImpairements("D:\\tempLibAndOntologies\\Practice_ontology1.owl");
    getGoals("D:\\tempLibAndOntologies\\Practice_ontology1.owl");
  }

  /* Load and modify ontology */
  public static JenaOWLModel loadOntology(String filePath) {

    JenaOWLModel owlModel = null;

    File initialFile = new File(filePath);
    try {
      InputStream targetStream = new FileInputStream(initialFile);
      try {
        owlModel = ProtegeOWL.createJenaOWLModelFromInputStream(targetStream);
      } catch (OntologyLoadException ex) {
        Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
      }
    } catch (FileNotFoundException ex) {
      Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
    }

    return owlModel;

  }

  public static LinkedHashMap<String, Object> getImpairements(String filePath) {
    LinkedHashMap<String, Object> impairmentValues = new LinkedHashMap<String, Object>();

    JenaOWLModel owlModel = loadOntology(filePath);

    OWLNamedClass impairmentClass = owlModel.getOWLNamedClass("IMPAIRMENT");
    Collection instances = impairmentClass.getInstances(true);

    for (Iterator iterator = instances.iterator(); iterator.hasNext();) {
      OWLIndividual individual = (OWLIndividual) iterator.next();

      String indvName = individual.getName().substring(individual.getName().indexOf("#") + 1);
      System.out.println("DEBUG␣individual␣impairment␣name:␣" + indvName);

      impairmentValues.put(indvName, indvName);

    }

    return impairmentValues;
```

```
  }

  public static LinkedHashMap<String, Object> getGoals(String filePath) {
    LinkedHashMap<String, Object> goalValues = new LinkedHashMap<String, Object>();

    JenaOWLModel owlModel = loadOntology(filePath);

    OWLNamedClass goalClass = owlModel.getOWLNamedClass("GOAL");
    Collection instances = goalClass.getInstances(true);

    for (Iterator iterator = instances.iterator(); iterator.hasNext();) {
      OWLIndividual individual = (OWLIndividual) iterator.next();

      String indvName = individual.getName().substring(individual.getName().indexOf("#") + 1);
      System.out.println("DEBUG␣individual␣goal␣name:␣" + indvName);

      goalValues.put(indvName, indvName);

    }

    return goalValues;
  }

  public static String getPractices(String impairment, String goal, String filePath) {

    String practices = "PRACTICES:␣\n";

    JenaOWLModel owlModel = loadOntology(filePath);

    OWLNamedClass goalClass = owlModel.getOWLNamedClass("PRACTICE");
    Collection instances = goalClass.getInstances(true);

    OWLObjectProperty adressesProperty = owlModel.getOWLObjectProperty("addresses");
    OWLObjectProperty isForProperty = owlModel.getOWLObjectProperty("is_for");

    for (Iterator iterator = instances.iterator(); iterator.hasNext();) {
      OWLIndividual individual = (OWLIndividual) iterator.next();

      String indvName = individual.getName().substring(individual.getName().indexOf("#") + 1);
      System.out.println("DEBUG␣practice:␣" + indvName);

      String indvadressesName = "";
      String indisforName = "";

      OWLIndividual adressesIndividual = (OWLIndividual) individual.getPropertyValue(adressesProperty);
      if (adressesIndividual != null) {
        System.out.println("Debug␣adressesIndividual␣=␣" + indvadressesName);
      }

      OWLIndividual isForIndividual = (OWLIndividual) individual.getPropertyValue(isForProperty);
      if (isForIndividual != null) {
        indisforName = isForIndividual.getName().substring(isForIndividual.getName().indexOf("#") + 1);
        System.out.println("Debug␣isForIndividual␣=␣" + indisforName);
      }
```

```
      if (indvadressesName.compareTo(impairment) == 0 && indisforName.compareTo(goal) == 0) {
        practices = practices + indvName + "\n";
      }

    }

    if (practices.compareTo("PRACTICES:␣\n") == 0) {
      practices = practices + "␣There␣are␣no␣asserted␣practices␣in␣the␣ontology␣for␣the␣selected␣impairment␣a
    }

    return practices;

  }

  public static String getPossibleGoals(String impairment, String goal, String filePath) {
    String possibleGoals = "POSSIBLE_GOALS:␣\n";

    OWLOntologyManager manager = OWLManager.createOWLOntologyManager();

    File initialFile = new File(filePath);
    try {
      InputStream targetStream = new FileInputStream(initialFile);
      try {

        // Pellet reasoner that will read rules
        OWLReasonerFactory reasonerFactory = PelletReasonerFactory.getInstance();
        OWLReasoner reasoner = reasonerFactory.createReasoner(ontology, new SimpleConfiguration());
        OWLDataFactory factory = manager.getOWLDataFactory();
        PrefixOWLOntologyFormat pm = (PrefixOWLOntologyFormat) manager.getOntologyFormat(ontology);
       //  pm.setDefaultPrefix(BASE_URL + "#");

        //get class and its individuals
        org.semanticweb.owlapi.model.OWLClass classPossibleGoals = factory.getOWLClass("POSSIBLE_GOAL", pm);

        for (OWLNamedIndividual pgIndv : reasoner.getInstances(classPossibleGoals, false).getFlattened()) {
          System.out.println("Possible␣goal␣:␣" + renderer.render(pgIndv));
          possibleGoals = possibleGoals + renderer.render(pgIndv) + "\n";
        }

      } catch (OWLOntologyCreationException ex) {
        Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
      }
    } catch (FileNotFoundException ex) {
      Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
    }

    if (possibleGoals.compareTo("POSSIBLE_GOALS:␣\n") == 0) {
      possibleGoals = possibleGoals + "␣There␣are␣no␣asserted␣possible␣goals␣in␣the␣ontology␣for␣the␣selected␣
    }


    return possibleGoals;

  }
```

```
  public static String getTechnology(String impairment, String goal, String filePath) {
   String technology = "TECHNOLOGY:␣\n";

   OWLOntologyManager manager = OWLManager.createOWLOntologyManager();

   File initialFile = new File(filePath);
   try {
     InputStream targetStream = new FileInputStream(initialFile);
     try {
       org.semanticweb.owlapi.model.OWLOntology ontology = manager.loadOntologyFromOntologyDocument(target

       // Pellet reasoner that will read rules
       OWLReasonerFactory reasonerFactory = PelletReasonerFactory.getInstance();
       OWLReasoner reasoner = reasonerFactory.createReasoner(ontology, new SimpleConfiguration());
       OWLDataFactory factory = manager.getOWLDataFactory();
       PrefixOWLOntologyFormat pm = (PrefixOWLOntologyFormat) manager.getOntologyFormat(ontology);
     //  pm.setDefaultPrefix(BASE_URL + "#");

       //get class and its individuals
       org.semanticweb.owlapi.model.OWLClass classTechnology = factory.getOWLClass("GOAL_PRACTICE_TECHNOLO

       for (OWLNamedIndividual pgIndv : reasoner.getInstances(classTechnology, false).getFlattened()) {
         System.out.println("Technology:␣" + renderer.render(pgIndv));
         technology = technology + renderer.render(pgIndv) + "\n";
       }

     } catch (OWLOntologyCreationException ex) {
       Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
     }
   } catch (FileNotFoundException ex) {
     Logger.getLogger(OntologyManager.class.getName()).log(Level.SEVERE, null, ex);
   }

   if (technology.compareTo("TECHNOLOGY:␣\n") == 0) {
     technology = technology + "␣There␣are␣no␣asserted␣technologies␣in␣the␣ontology␣for␣the␣selected␣impa
   }


   return technology;

  }

}

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

package efa;

import java.io.Serializable;

import java.util.Map;
```

```java
import javax.faces.bean.ManagedBean;

import javax.faces.bean.SessionScoped;


/**
 *
 * @author Darko Androcec
 */
@ManagedBean(name = "Screen1Bean")
@SessionScoped
public class Screen1Bean implements Serializable{

    String personName;

    String selectedImpairment;

    String selectedGoal;

    private Map<String, Object> impairmentValues;

    private Map<String, Object> goalValues;

    String result;

   // private static final String ONTOLOGY1_PATH = "D:\\tempLibAndOntologies\\Practice_ontology1.owl";

    // ontology on Mac
    private static final String ONTOLOGY1_PATH = "/Users/ealmami/Desktop/ontology/practice.owl";
    /**
     * Creates a new instance of Screen1Bean
     */
    public Screen1Bean() {



        impairmentValues = OntologyManager.getImpairements(ONTOLOGY1_PATH);
        goalValues = OntologyManager.getGoals(ONTOLOGY1_PATH);



    }

    public String getPersonName() {
        return personName;
    }

    public void setPersonName(String personName) {
        this.personName = personName;
    }

    public Map<String, Object> getGoalValues() {
        return goalValues;
    }
```

```
    public void setGoalValues(Map<String, Object> goalValues) {
        this.goalValues = goalValues;
    }


    public String getSelectedImpairment() {
        return selectedImpairment;
    }

    public void setSelectedImpairment(String selectedImpairment) {
        this.selectedImpairment = selectedImpairment;
    }

    public String getSelectedGoal() {
        return selectedGoal;
    }

    public void setSelectedGoal(String selectedGoal) {
        this.selectedGoal = selectedGoal;
    }

    public Map<String, Object> getImpairmentValues() {
        return impairmentValues;
    }

    public void setImpairmentValues(Map<String, Object> impairmentValues) {
        this.impairmentValues = impairmentValues;
    }

    public String getResult() {

        if (personName == null || personName.length() == 0){
            result = "Result";
        }
        else{
            result = "PERSON:␣" + personName + "\n";
            result = result + "GOAL:␣" + selectedGoal.replaceAll("_", "␣") + "\n";

            // get practices from the ontology
            result = result + OntologyManager.getPractices(selectedImpairment, selectedGoal, ONTOLOGY1_PATH
        }

        return result;
    }

    public void setResult(String result) {
        this.result = result;
    }


}

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
```

```
 */
package efa;

import java.io.Serializable;

import java.util.Map;

import javax.faces.bean.ManagedBean;

/**
 *
 * @author Darko Androcec
 */
@ManagedBean(name = "Screen2Bean")
@SessionScoped
public class Screen2Bean implements Serializabl{

    String selectedImpairment;

    String selectedGoal;

    private Map<String, Object> impairmentValues;

    private Map<String, Object> goalValues;

    String result;

   // private static final String ONTOLOGY2_PATH = "D:\\tempLibAndOntologies\\PossibleGoal_ontology2.owl";
       // ontology on Mac
    private static final String ONTOLOGY2_PATH = "/Users/ealmami/Desktop/ontology/practice.owl";

    /**
     * Creates a new instance of Screen1Bean
     */
    public Screen2Bean() {

        impairmentValues = OntologyManager.getImpairements(ONTOLOGY2_PATH);

    }

    public String getPersonName() {
        return personName;
    }

    public void setPersonName(String personName) {
        this.personName = personName;
    }

    public Map<String, Object> getGoalValues() {
        return goalValues;
    }

    public void setGoalValues(Map<String, Object> goalValues) {
        this.goalValues = goalValues;
    }
```

```
    public String getSelectedImpairment() {
        return selectedImpairment;
    }

    public void setSelectedImpairment(String selectedImpairment) {
        this.selectedImpairment = selectedImpairment;
    }

    public String getSelectedGoal() {
        return selectedGoal;
    }

    public void setSelectedGoal(String selectedGoal) {
        this.selectedGoal = selectedGoal;
    }

    public Map<String, Object> getImpairmentValues() {
        return impairmentValues;
    }

    public void setImpairmentValues(Map<String, Object> impairmentValues) {
        this.impairmentValues = impairmentValues;
    }

     public String getResult() {

        if (personName == null || personName.length() == 0){
            result = "Result";
        }
        else{

            result = "PERSON: " + personName + "\n";
            result = result + "IMPAIRMENT: " + selectedImpairment.replaceAll("_", " ") + "\n";
            result = result + "GOAL: " + selectedGoal.replaceAll("_", " ") + "\n";

            // get practices from the ontology
            result = result + OntologyManager.getPractices(selectedImpairment, selectedGoal, ONTOLOGY2_PATH

            // get possible goals using pellet reasoner and rules defined in the ontology
            result = result + OntologyManager.getPossibleGoals(selectedImpairment, selectedGoal, ONTOLOGY2
        }

        return result;
    }

    public void setResult(String result) {
        this.result = result;
    }
}

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
```

```
 */
package efa;

import java.io.Serializable;
import javax.faces.bean.ManagedBean;
import javax.faces.bean.SessionScoped;

/**
 *
 * @author Darko Androcec
 */
@ManagedBean(name = "Screen3Bean")
@SessionScoped
public class Screen3Bean implements Serializable{

    String personName;
    String selectedImpairment;
    String selectedGoal;
    private Map<String, Object> goalValues;

    String result;

    // private static final String ONTOLOGY3_PATH = "D:\\tempLibAndOntologies\\Practice_Technology_ontology3.

    // ontology on Mac
    private static final String ONTOLOGY3_PATH = "/Users/ealmami/Desktop/ontology/practice.owl";

    /**
     * Creates a new instance of Screen1Bean
     */
    public Screen3Bean() {

        impairmentValues = OntologyManager.getImpairements(ONTOLOGY3_PATH);
        goalValues = OntologyManager.getGoals(ONTOLOGY3_PATH);

    }

    public String getPersonName() {
        return personName;
    }

    public void setPersonName(String personName) {
        this.personName = personName;
    }

    public Map<String, Object> getGoalValues() {
        return goalValues;
    }

    public void setGoalValues(Map<String, Object> goalValues) {
        this.goalValues = goalValues;
    }


    public String getSelectedImpairment() {
```

```
        return selectedImpairment;
    }

    public void setSelectedImpairment(String selectedImpairment) {
        this.selectedImpairment = selectedImpairment;
    }

    public String getSelectedGoal() {
        return selectedGoal;
    }

    public void setSelectedGoal(String selectedGoal) {
        this.selectedGoal = selectedGoal;
    }

    public Map<String, Object> getImpairmentValues() {
        return impairmentValues;
    }

    public void setImpairmentValues(Map<String, Object> impairmentValues) {
        this.impairmentValues = impairmentValues;
    }

     public String getResult() {

        if (personName == null || personName.length() == 0){
            result = "Result";
        }
        else{

            result = "PERSON:␣" + personName + "\n";
            result = result + "IMPAIRMENT:␣" + selectedImpairment.replaceAll("_", "␣") + "\n";

            // get practices from the ontology
            result = result + OntologyManager.getPractices(selectedImpairment, selectedGoal, ONTOLOGY3_PATH

             // get technology using pellet reasoner and rules defined in the ontology
            result = result + OntologyManager.getTechnology(selectedImpairment, selectedGoal, ONTOLOGY3_PAT
        }

        return result;
    }

    public void setResult(String result) {
        this.result = result;
    }
}
```

Appendix C

Taxonomy Of The Semantics Of Learning Disabilities

DISSABILITY	CONSEQUENCE	PROPOSED PRACTICES	TASKS – IN THE CLASSROOM	ASSISTIVE TECHNOLOGIES
Autism	Little or no eye contact	• Use visual aids • Use colour coding • Provide positive praise • use reinforcement • Change rewards frequently	Reading	• Videos • Talking electronic device • Books on tapes • Electronic text books • Multimedia presentation formats
	Little or no eye contact	• keep students engaged • use reinforcement •	spelling	• Facial expression recogniser
	Little or no facial expression	• keep students engaged • use interactive tasks • daily engagement in group discussions • daily engagement in group tasks • use reinforcement	Presenting	• software applications • Laptops
	Little or no body language	• keep students engaged • use interactive tasks • daily engagement in group discussions	Dance	• YouTube videos

		daily engagement in group tasks • use reinforcement • demonstrate rather than explain		
	Little or no body language		Group-work	No technology identified
	Easily distracted	• Stimulate students interest • Use visual aids • Use verbal descriptions • Use voice variation • Provide a separate quiet room for extended time tests • Face the class when teaching • Avoid placing hands near your mouth • Call on students by name to maintain their attention • Use index cards • use reinforcement • use rewards • Change rewards frequently • Link reading tasks to students interests	Reading	• Use of highlighter tool on computer • Laptops • Apple iPod • Software applications
	Easily distracted	• Work tasks should be in order	Writing	• Voice recognition software

		• Use variation in tasks • use reinforcement • use rewards • Change rewards frequently • Create schedule • Link work to students interest		• Electronic dictionary • Electronic thesaurus
	Easily distracted	• Use students interests (pictures) to introduce new tasks • Use picture cards to convey ideas • Use rewards to encourage students • Use consequences to encourage students • Learn what works with each child • Use tapping rhythms • Use clapping rhythms • Link work to students interest	Music	• Software applications • Musical computer games
	Easily distracted	• Work tasks should be in order • Use variation in tasks • use reinforcement • use rewards • Change rewards frequently • Link work to students	Mathematics	• Hand held speaking calculators

		interest		
	Unable to form friendships with peers	• Eliminate stress	Group work	• Facial expression recogniser
	Unable to share emotions on a social level	• Continuous encouragement		• Facial expression recogniser
	Low self esteem	• Continuous encouragement • use reinforcement • use rewards • Change rewards frequently •	Group work	
	No spoken language	• Use gestures • Use sign language • Teach rest of class sign language	Speaking	• Videos with subtitles
	No spoken language	• Use gestures • Use sign language • Teach rest of class sign language	Reading	• Videos with subtitles
	Delayed speech	• Use picture exchange as a method of communication •	Speaking	No technology identified
	Delayed speech	• Use picture exchange as a method of communication	Reading	No technology identified

	Inability to listen selectively	• Use picture exchange	Writing	No technology identified
	Inability to listen selectively	• Use picture exchange	Reading	No technology identified
	Repetitive use of language	• Use picture exchange	Speaking	No technology identified
	Obsessed with a certain topic	• Focussing students attention before communication • Call student by name • Use clear simple requests • Give instructions one at a time	Reading	No technology identified
	Obsessed with a certain topic	• Focussing students attention before communication • Use clear simple requests • Give instructions one at a time	Writing	No technology identified
	Obsessed with a certain object	• Focussing students attention before communication • Call student by name • Use clear simple requests • Give instructions one at a time • Reduce distractions in	Writing	No technology identified

Appendix D

Taxonomy Of The Semantics Of Learning Disabilities and Impairments

IMPAIRMENTS			PRACTICES
Social Interaction Skills	Indifference to other people		Know the things which may upset the child
	Inability to initiate social contact		Be a friend
	Inability to maintain social contact		
	Inappropriate approaches to other people		Help the child to communicate with others
	odd approaches to other people		
	Poor organizational skills		• use schedules and calendars • maintain lists of assignments • Help the student to use .to do. lists and checklists • place pictures on containers and locker • use picture cues in lockers
	No attention to the response given		exaggerate social gestures and expressions
	Stilted and overly formal interaction, even in the most able individuals		Stay near the child when activities are new or likely to cause confusion Plan personal social lessons to emphasise social rules
	Difficulties interacting with peers		The use of social skills stories
	Difficulties interacting with adults		
	Dislike Transitioning between activities		The teaching of key social skills in all lessons
	Dislike Transitioning between locations		
	Dislike Change of routine (timetable or staff)		Let the child know if you are about to change an activity
	Do not like Sharing		Using a visual cue
	Do not like Waiting		Use an egg timer for younger children
	Sensory difficulties		Use social stories to help the child initiate communication
	Cannot accept Turn taking		Make a request and finish a conversation
	Cannot accept structured time (free play, assembly, break and lunch time)		Encourage the child to observe how others behave and to follow the example
	Dislike Group work		Visual rules
	Difficulty reading social cues Difficulty reading social situations		Social stories can help the child to be quiet
	Difficulty understanding social cues Difficulty understanding social situations		A sequence of appropriate behaviours in pictorial form
	Withdraws from social situations		Using peer support
	Unusual responses in social situations		Provide the child with 1:1 training for different situations
	No observable interest or concern in interacting with other people		Provide the child with small group training for different situations
	Reject unsolicited social contact		Using circle time and buddying approaches
	Reject unsolicited physical contact		

	Do not initiate social approaches	Use simple language that is concise and clearly understood
	Active but odd	Provide visual supports where practical
	Use of non-verbal behaviours	Avoid sarcasm
	Problems developing peer relationships	Talk to the child directly
	Lacking in the imaginative qualities of social play	Praise all attempts to communicate
	Do not accept spontaneous showing	Speak slowly to give time for understanding and response
	Do not accept sharing of interests	Use familiar words and teach them to ask when they are confused
	Do not accept social emotional reciprocity	Teach new words in a variety of contexts
	Difficulties in forming reciprocal peer relationships	Encourage the child to listen
	Difficulties in forming reciprocal friendships	Accept the child's best verbal efforts
	Difficulties in picking up on non-verbal	Create a home-school communication book
	Difficulties in picking up on emotional cues	
	Taking what is said to them literally	Use simple drawings to encourage conversation
	Difficulties in picking up on social cues	Provide opportunities for the child to practise his language skills
	Unpredictable emotional responses for no reason	Provide other means of developing their ability to communicate
	Deficits in the capacity to share attention	using physical prompts,
	Deficits in the capacity to share emotion with others	Pictures or computer programmes to teach communication skills
	Deficits in the capacity to understand the feelings of others	Encourage those communicating with the child with an ASD to adjust their skills
Language and Communication Skills	Difficulty using their language to communicate effectively	use Comic Strip Conversations
	Difficulties in using their language in an appropriate manner	teach appropriate opening comments
	Difficulty with the social aspects of language	
	Interact in socially inappropriate ways	
	An inability to understand the facial expression	
	An inability to understand the body language	
	An inability to empathise with others	
	A literal understanding of language	
	Difficulty communicating thoughts	
	Difficulty communicating needs verbally	
	Difficulty communicating non-verbally	
	Difficulty with non-verbal communication	
	Repetitive speech patterns	
	Inappropriate facial expressions	
	Unusual use of gestures	
	Lack of eye contact	

	Strange body postures	
	Lack of mutual or shared focus of attention	
	Lack of expressive language skills	
	Differences in oral language	
	Odd pitch or intonation in language	
	Restricted vocabulary	
	Difficulty changing topics	
	Difficulty with pragmatics of conversation	
	Problems initiating the communication	
	Difficulty using unwritten rules	
	Inability to maintain conversation on a topic	
	Inappropriate interrupting	
	Inflexibility in style of conversation,	
	Delayed language development	
	Problems starting conversations	
	Problems sustaining conversations	
	Stereotyped language	
	Restricted imaginative	
	Imitative play	
	Problems understanding spoken language	
	Problems understanding verbal instructions	
	Not responding when spoken to	
	Solo play	
	Do not accept group play	
Imagination with A Restricted Range of Behaviours, Activities and Interests	Preoccupation with Seemingly Irrelevant Details	
	Engagement in stereotypical behaviour	
	Encompassing narrow interests to the exclusion of other activities	
	Difficulty with planning	
	Difficulty with organisation	
	Difficulty with change in routine	
	Excessive anxiety	
	Repeatedly ask questions	
	lack of appreciation	
	A blurred distinction between fantasy and reality	
	Displays preoccupations with specific themes or objects	
	Likes order	

	Line up toys repeatedly	
	Engages in unusual behaviours	
	Unusual response to loud noises	
	Unusual response to other sensory stimuli	
	Restricted range of interests	
	Preoccupation with one specific interest or object	
	Inflexible adherence to a non-functional routine	
	Stereotypic and repetitive motor mannerisms	
	Preoccupation with parts of objects	
	Fascination with movement	
	Insistence on sameness	
	Resistance to change	
	Over-focus on particular topics	
	Rigid adherence to routines/rituals	
	Repetitive, stereotyped motor mannerisms	
	Preoccupation with object parts rather than whole	
	Preference for only one or a few activities	
	Difficulty with transitions	
	Difficulties maintaining attention	
	Difficulties moving from one activity to another	
	Less likely to pick up on the 'gist' of a situation or activity	
Additional difficulties might indicate	Abnormal sensory perception	
	Motor control problems	
	Eating irregularities	
	Drinking irregularities	
	Sleeping irregularities	
	Restricted attention span	
	Inability to block out distractions	
	Over-compliance	
	The individual is too easily led	
	Speaking out of turn or interrupting	

Learning	Deficits in paying attention to relevant cues	
	Deficits in paying attention to information	
	Deficits in paying attention to in attending to multiple cues	
	Receptive and expressive language impairments	
	Deficits in concept formation	
	Deficits in abstract reasoning	
	Inability to plan	
Unusual patterns of attention	Difficulty paying attention to relevant cues	
	Difficulty paying attention to the information in their environment	
	Focus their attention only on a restricted part of the environment	
Unusual responses to sensory stimuli	Hyposensitivity to sensory stimulation	
	Hyporeactive to sensory stimulation	
	Hyperreactive to sensory stimulation	
	Aversive responses to particular environmental stimuli	
	Sensory seeking behaviour	
	Removes self from the source by leaving a room or people	
	Needs one person/thing at a time	
	Fascination with looking objects or people	
	Fascination with smelling objects or people	
	Fascination with licking objects or people	
Anxiety	Inability to express oneself	
	Difficulties with processing sensory information	
	Fearing some sources of sensory stimulation	
	High need for predictability	
	Difficulty with change	
	Difficulty understanding social expectations	
	Insistence on sameness	• prepare the student for potential change, wherever possible • use pictures, schedules and • social stories to indicate impending changes