DEVELOPMENT OF A FRAMEWORK FOR EVALUATING THE QUALITY OF INSTRUCTIONAL DESIGN ONTOLOGIES

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ABSTRACT

Instructional Design (ID) ontology can be used to formally represent knowledge about the teaching and learning process, which contributes to automatic construction of personalised eLearning experiences. While ID ontologies have been continuously improved and developed over recent years, there are concerns regarding what makes a quality ID ontology. This study proposes a framework for evaluating the quality of an ID ontology by synthesising the crucial elements considered in the ID ontologies developed to date. The framework would allow a more precise evaluation of different ID ontologies, by demonstrating the quality of each ontology with respect to the set of crucial elements that arise from the ontology. This study also gives an overview of the literature on ID ontology, as well as the implications for future research in this area.

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CHAPTER 1 INTRODUCTION

Background

The eLearning attributes of on-demand availability, relatively low cost, and removal of the barriers of time and distance have contributed to the popularity of this mode of learning; attributes that are not always possible to achieve from the standard or traditional way of learning (Devedžić, 2003). Despite the advances that have been made in eLearning systems, there is increasing demand for more sophisticated features. These include delivering personalised learning content that responds to learners' needs and competencies, as well as providing sufficient authoring support to the course designers in eLearning systems (Mizoguchi & Bourdeau, 2000).

With the emergence of the Semantic Web (Berners-Lee & Fischetti, 1999; Berners-Lee, Hendler, & Lassila, 2001), Ontology, as one of the essential building blocks in the infrastructure of the Semantic Web, has been proposed for addressing current eLearning limitations. For example, Mizoguchi and Bourdeau (2000) note that ontology has improved the support for authoring of courses and personalisation of learning provided within current eLearning systems. Different ontologies could be developed for eLearning which cover a number of areas and aspects of teaching and learning. Because the languages used for expressing these ontologies are machine-understandable, such ontologies could be used in eLearning systems to at least semi-automate some of the complex tasks of learning personalisation and course authoring (Paquette, Marino, Lundgren-Cayrol, & Léonard, 2008).

According to Aroyo and Dicheva (2004), specifying reusable chunks of learning content and defining an abstract way of describing designs for different units of learning (for example, courses and lessons) are two of the most current research issues in the eLearning community, which have been considered as the major barriers to improving eLearning. This study focuses on issues relating to the representation of designs for different units of learning using ontology, that is, instructional design (ID) ontology.

Motivation and Objectives

Motivation

It is well known that developing an ID ontology is quite a complex issue, because there have always been different opinions regarding the concepts included in an instructional design model (Devedžić, 2006). Nevertheless, ID ontology is one of the essential elements which contributes to the delivery of a quality web-based learning experience (Paquette, 2003). ID ontology not only supports the creation of instructional designs that are shareable and reusable between different eLearning systems, but it also enables and facilitates the computational reasoning in eLearning systems so that the automatic construction of personalised eLearning experience can be achieved (Lama, Sanchez, Amorim, & Vila, 2005).

While ID ontologies have being continuously improved and developed over recent years, researchers have expressed various concerns in their own studies regarding the challenges in developing an ID ontology that makes it possible to fulfil its intended function or purpose. However, none of the studies reported about each ID ontology have referenced other research, or have explicitly built upon the findings of those who have published previously; thus the findings have not been brought together or compared. Furthermore, none of the researchers have drawn together the issues discussed in the many studies to develop a set of key attributes of ID ontologies which could help solve current eLearning problems. Therefore, this study aims to identify the crucial attributes or elements across all published ID ontology studies and develop a framework based on these elements which could be used for evaluating the *quality* of an ID ontology.

What is Quality?

'Quality' is a term that is not usually formally defined (Kim, Fox, & Gruninger, 1995). However, it is necessary to define quality in this study for two reasons: first, the definition of the term quality provides a benchmark for the identification of the crucial elements associated with the ID ontology, since these elements contribute to achieve the quality requirements defined for an ID ontology; second, the definition of the term quality provides the measurement for what is accounted to be a quality ID ontology. According to the ISO 9126[1] of the International Organisation for Standardisation, quality is defined as "[t]he totality of characteristics of an entity that bears on its ability to satisfy stated and implied needs" (ISO, 2001, p. 31). This definition is adopted for this study. That is to say, for an ID ontology to be of high quality, it must possess certain characteristics that satisfy its intended function or purpose. The intended purposes of an ID ontology include, but not be limited to:

1. being able to increase the expressiveness of the instructional design and facilitate computational reasoning (Lama, et al., 2005);

[1] ISO 9126 is the software product evaluation standard from the International Organization for Standardization (ISO, 2001).

2. enabling instructional designs to be more easily searched, shared and reused (Knight, Gašević, & Richards, 2005);
3. being able to support automatic construction of personalized eLearning experience (Van Marcke, 1992);
4. being able to support the creation of pedagogically sound instructional designs (Mizoguchi & Bourdeau, 2000).

Research Objectives

The objectives of this study are to:

1. identify the crucial elements that influence the quality of an ID ontology through a systematic examination of the developed ID ontologies;
2. develop a framework for evaluating the quality of ID ontologies by synthesising the crucial elements identified.

Significance

This study is significant first, because it identifies the crucial elements for developing a quality ID ontology. Through an analysis of several ID ontologies an interpretation is allowed for which is beyond the scope of any single ID ontology. This, in turn, would inform the development of ID ontologies and contribute to a quality ID ontology that meets the needs of both learners and instructional design authors. Second, the quality framework developed in this study will serve as a guideline for practitioners in their development and evaluation of any ID ontology. Such framework would also allow a more precise evaluation of different ID ontologies, by demonstrating the quality of each ontology with respect to the set of crucial elements that arise from the ontology. Third, this study is significant because it provides a comprehensive literature review of the ID ontology research field (not previously available), which may suggest provide future research directions in this area.

Thesis Structure

This study is organised into five chapters. Chapter 1 gives an introduction to the study. It begins by describing the background of the study and then gives an overview of the factors that led the researcher to conduct the study, describes the research objectives and the significance of the study.

Chapter 2 provides a review of the literature. It begins by presenting a general background to eLearning and ontology, and then proceeds to an introduction of

Instructional Design (ID) Ontologies. Finally, the crucial issues in the development of an ID ontology are reviewed and discussed.

Chapter 3 describes and justifies the research methodology used in this study, as well as the limitations of the research design.

Chapter 4 presents the quality framework developed in this study. It provides the description and justification for each crucial element considered in the framework as well as the category to which they belong. Also, the expert feedback regarding the developed framework is reported.

Finally, the conclusion and future work needed for this study is summarised in Chapter 5. Limitations of the study are also discussed.

CHAPTER 2 LITERATURE REVIEW

This chapter begins by presenting a general background to eLearning and ontology, and then proceeds to an introduction of Instructional Design (ID) ontology and discussion of ID ontology characteristics that contribute to a quality ID ontology. Finally, the crucial issues in the development of an ID ontology are reviewed and discussed.

Background

eLearning

The Definition of eLearning

eLearning is defined by Paulsen (2003) as interactive learning in which the learning content is available online and provides automatic feedback to the student's learning activities. eLearning may also be considered as including not only the Internet as technological support for learning but other media and resources as well (Kaplan-Leiserson, 2000). This research adopts Paulsen's interpretation of the term eLearning. That is, eLearning requires Internet access to learning material and for monitoring learners' activities and it includes such supporting features as communication and collaboration between learners and between learners and instructors.

The Problems of eLearning

eLearning has removed the barriers of time and distance, thus enabling people to start learning anytime and anywhere at a minimal cost (Aroyo & Dicheva, 2004). Although eLearning has become popular with its self-paced character, it has not reached the level of sophistication that many course developers and learners require. The challenges relate to the support for authoring activities and the personalisation services in eLearning systems. Mizoguchi and Bourdeau (2000) pointed out that more time is often required by course designers to organise pedagogically sound learning materials in eLearning systems than in traditional settings due to the insufficient authoring support provided in the current systems. Devedžić (2006) found that current eLearning systems are unable to provide learners with personalised learning content that responds to their individual learning needs and competencies. With the consideration of overcoming these challenges so that teachers' workloads could be decreased and learners' needs could also be satisfied in the eLearning environment, ontology has been proposed to solve the major eLearning problems (Mizoguchi & Bourdeau, 2000).

To facilitate interoperability among different eLearning systems, many eLearning standards have been proposed. These standards enable the learning resources to be reused and shared to some extent among different systems. However, they have some limitations. For example, IEEE[2] Learning Object Metadata (LOM), IMS[3] Learning Design, and ADL[4] Sharable Courseware Object Reference Model (SCORM) only unofficially define the semantics of the learning objects, thus the extensions of learning objects are difficult for other systems to fully access and understand (Ullrich, 2003). Furthermore, the modelling language of these standards, XML-Schema, is not expressive enough to describe the semantics associated with all their elements (Lama, et al., 2005). Nevertheless, it has been suggested that formally and explicitly expressing these learning standards by using another kind of modelling language such as ontology would enhance the interoperability as well as automate some difficult tasks in the eLearning systems such as the task of course authoring and personalisation (Lama, et al., 2005).

Introduction to Ontology

What is Ontology?

Ontology is a term originally from philosophy, which refers to the subject of existence. In its philosophical sense, ontology is used to determine what entities and types of entities exist, and thus it serves as a tool to study the structure of the world. In computer science it is usually taken to be a model of the world (Horrocks, 2007); it is “a specification of a conceptualisation” (Gruber, 1993, p. 199) which introduces vocabulary describing various aspects of the domain being modelled, and provides an explicit specification of the intended meaning of the vocabulary.

The Semantic Web, proposed by Berners-Lee (1999; 2001), is the new-generation web that tries to represent information so that it can be used by machines not just for display purposes but also for automation, integration and reuse between different systems. Ontology is one of the essential Semantic Web technologies and the most important component in achieving semantic interoperability of Web resources, since it helps establish a shared and common understanding of any domain that can be

[2] The Institute of Electrical and Electronics Engineers (IEEE) is an international non-profit, professional organization for the advancement of technology related to electricity (IEEE, 2009).
[3] IMS is a consortium of global eLearning software companies and users (IMS Global Learning Consortium, 2009).
[4] ADL (Advanced Distributed Learning) Initiative was established in 1997 to develop and implement learning technologies across the U.S. Department of Defence and federal government (ADL, 2009).

communicated between different systems (Mizoguchi & Bourdeau, 2000). Apart from eLearning, ontology has also been used to address the personalisation requirements, for example, in e-commerce (Stefani, Vassiliadis, & Xenos, 2006).

Ontologies for eLearning

What Can the Ontology do for eLearning?

Ontology is proposed to solve the major problems in the area of eLearning, including the support for authoring and personalisation (Mizoguchi & Bourdeau, 2000). Since ontology helps describe a formal and shared conceptualisation for the eLearning domain, it allows the learning resources to be reused and shared among different eLearning systems (Devedžić, 2006). In particular, ontology provides the formal definition of instructional knowledge which enables the software agents in eLearning systems to provide intelligent authoring support, such as assistance to the authors in the form of hints, recommendations, and so on (Aroyo & Dicheva, 2004). Furthermore, ontology helps eLearning systems to combine domain knowledge, pedagogical, and application-specific knowledge to structure learner models, which in turn enables learning personalisation (Kizilkaya, Torun, & Askar, 2007).

Ontology-Based Frameworks for eLearning

To realise the benefits that ontology brings to eLearning, researchers, in particular Mizoguchi and Bourdeau (2000), Dolog and Sintek (2004), Jovanović, Gašević, and Devedžić (2006), Arapi, Moumoutzis, and Mylonakis (2007), have proposed eLearning frameworks based on ontology. Basically, their eLearning frameworks suggest including four ontologies to generate personalised learning content. These are: Learner Resource Ontology (Devedžić, 2006) for describing learning resources; Domain Ontology (Gascuena, Fernandez-Caballero, & Gonzalez, 2006; Jovanović, et al., 2006) for describing domain information such as the subject a learning resource belongs to; Learner Ontology (Heckmann, Schwartz, Brandherm, Schmitz, & von Wilamowitz-Moellendorff, 2005; Arapi, Moumoutzis, & Mylonakis, 2007) for describing learners with respect to learning background, preferences, goals and so on; and Instructional Design Ontology (Knight, et al., 2005; Lama, et al., 2005; Arapi, Moumoutzis, & Mylonakis, 2007; Mizoguchi, Hayashi, & Bourdeau, 2007) for representing knowledge about the teaching and learning process. Instructional Design Ontology is not considered in the Dolog and Sintek (2004) framework, but it is included in the frameworks of the other researchers.

Other ontologies for eLearning include Context Ontology, suggested by Jovanovic et al. (2006), to increase the reusability of instructional designs and learning objects. This ontology bridges instructional design and learning object content, and contains data about how instructional designs and learning objects are used in practice, such as prerequisites, competencies, and evaluation applicable to a specific learning object. Another eLearning ontology developed is the ontology for describing instructional roles of learning objects suggested by Ullrich (2004). This ontology clearly separates the pedagogical roles from the description of learning objects, thereby enhancing the reusability of learning objects. This ontology has been evaluated and implemented in the Jovanović et al. (2006) framework.

Instructional Design Ontology

The Definition of ID Ontology

In the ontology-based eLearning frameworks discussed above, Instructional Design (ID) Ontology is commonly considered to be the ontology which formally represents knowledge about the teaching and learning process; it is one of the crucial elements that contributes to the delivery of a quality web-based learning experience (Paquette, 2003). In the context of IMS-LD specification, 'instructional design' is known as 'learning design' (Koper & Tattersall, 2005), which has been defined as "a description of a method enabling learners to attain certain learning objectives by performing certain learning activities in a certain order in the context of a certain learning environment" (Koper & Olivier, 2004, p. 99).

Why We Need ID Ontology

The general purposes that an ID ontology will meet have been suggested by the ID ontology developers and the experts in the field. Lama, Sanchez, Amorim, and Vila (2005), who proposed the first ID ontology, point out that ID ontology should be used to increase the expressiveness of instructional designs in eLearning systems and facilitate computer reasoning for instructional designs. In addition, the ontology can enable instructional knowledge to be better shared and reused between eLearning systems. Mizoguchi and Bourdeau (2000), who developed the instructional design theory ontology OMNIBUS, suggest intergrating various educational theories with the ontology to provide support for the creation and validation of instructional designs against the educational theories. Knight, Gašević, and Richards (2005) demonstrated how easily ID ontology can enable instructional designs to be searched in a learning design repository. Furthermore, Van Marcke (1992) suggested using instructional knowledge for supporting automatic construction of personalized eLearning experience, which has been demonstrated by Arapi, Moumoutzis, and Mylonakis (2007), who developed and implemented ID ontology in their eLearning personalisation framework.

The Development of ID Ontology

Despite these developments, agreement has not been reached on how to design an ontology for instructional designs (Mizoguchi & Bourdeau, 2000). Researchers have put forward a number of issues that need to be considered in developing an ID ontology. These issues relate to the reusability of instructional designs (Amorim, Lama, Sanchez, Riera, & Vila, 2006; Knight, Gašević, & Richards, 2006), including support of learning standards, the use of concepts hierarchy, and selection of ontology language. Other issues relate to the personalisation of instructional designs (Arapi, Moumoutzis, & Mylonakis, 2007), including the consideration of learning style and domain knowledge. Other important challenges to consider are the application of instructional theories (Mizoguchi, et al., 2007), the proposed use of ontology axioms (Amorim, Lama, Sanchez, et al., 2006), and the availability of authoring tools for an ID ontology (Sanchez, Lama, Amorim, & Negrete, 2007).

The following sections elaborate these key issues for ID ontologies as discussed in the literature.

Support of Learning Design Standards

The standardisation of learning design facilitates the reusability of learning designs (Devedžić, 2006). IMS Learning Design (IMS-LD) has been regarded as the de facto standard for describing learning design, thus providing a standardised framework for describing the teaching and learning process in a unit of learning (Koper, 2006). IMS-LD was developed by Koper (2001) at the Open University of the Netherlands based on the Educational Modelling Language (EML). The IMS-LD is sufficiently flexible to describe instructional designs but it has a limitation in describing the semantics associated with its elements, due to its modelling language XML-Schema. A further limitation of the IMS-LD, as noted by Amorim, Lama, and Sanchez (2006), is its inability to define the hierarchical (is-a) taxonomies, properties of relations and semantic constraints between the learning design elements. Further, IMS-LD does not offer any support for authoring, production, or delivery of instructional design documents (Paquette, Lundgren-Cayrol, & Léonard, 2008).

To overcome the limitations of the IMS-LD, Lama et al. (2005) developed the first ID ontology called IMS-LD ontology which uses an ontology language that formally expresses the semantics associated with the elements of the IMS-LD. Therefore, their IMS-LD ontology is fully compliant with the IMS-LD specification. Similarly, Knight et al. (2005) proposed LOCO (Learning Objective Context Ontology), which is another ID ontology based on a direct translation of the IMS-LD modelling language.

The ID theory ontology OMNIBUS which was proposed by Mizoguchi, et al. (2007), also supports the transferability of developed instructional design models into the IMS-LD compliant documents. The ID ontology proposed by Arapi et al. (2007) exploited some elements and ideas from both IMS-LD and Learning Object Metadata (LOM). However, it is unclear from the literature whether or not the developed instructional design models using the ontology are compliant with the IMS-LD (Arapi, Moumoutzis, & Mylonakis, 2007).

ID ontologies that support the IMS-LD are differentiated into three levels of IMS-LD. According to the IMS Global Learning Consortium (2003), the IMS-LD specifies three levels of implementation and compliance. Learning design level A contains all the core vocabulary needed to model any pedagogical situation. To support more sophisticated behaviours, learning design levels B and C add three additional concepts to the specification. Level B adds Properties and Conditions to level A, which enable personalization and more elaborate sequencing and interactions based on learner portfolios. Level C adds Notification to the previous levels to describe which new activities are available for a role, based on certain outcome triggers. Currently, only the Lama et al. (2005) IMS-LD ontology supports all three levels of IMS-LD. Both LOCO and OMNIBUS support only Level A of the IMS-LD. However, it is unclear whether the ID ontology developed by Arapi, et al. and described in their publication (2007) supports any level of the IMS-LD. Nevertheless, the support of learning design standards has been seriously considered in the development of any ID ontology.

The Use of Concepts Hierarchy

An ontology language allows the formal definition of instructional designs, thus a new hierarchy of concepts can be created to organise the elements of instructional designs. The concepts hierarchy further increases the reusability of instructional designs

(Lama, et al., 2005). In the Lama, et al. (2005) IMS-LD ontology, abstract classes are introduced to improve the structure of the taxonomy by taking advantage of the inheritance and subsumption mechanisms. In particular, the *Item* class is used to link the *Learning Design* and *Learning Object* classes; it enables instructional designs to be indirectly linked to learning objects, rather than be stated in the instructional design, so that the instructional designs are more likely to be reused in different learning environments. Similarly, the *Resource Description* class (which is similar to the *Item* class in the IMS-LD ontology) in LOCO ontology (Knight, et al., 2005), was also proposed for separating references to the learning objects from an instructional design in order to increase the reusability of the instructional design.

Arapi, Moumoutzis, and Mylonakis (2007) suggested defining the requirements for the desired learning objects instead of explicitly specifying the required learning objects in the instructional design, by introducing a new class called *Learning Object Type* in the ID ontology. They believe that doing so would enable various instructional designs to be totally flexible and thus be reused in different systems because the learning objects are not pre-determined for any instructional design but are retrieved according to the specification at the system run-time.

Selection of Ontology Language

The Web Ontology Language (OWL) proposed by the W3C[5] is the standard language for expressing any ontology in the Web (W3C, 2007). It has been used in all existing ID ontologies as the modelling language, with the exception of OMNIBUS ontology which uses its own modelling language named HOZO. Since OWL is the standard language for expressing ontologies in the Web, the instructional design that was developed with the OWL format of the ID ontology could be more easily reused in different eLearning systems. The current OMNIBUS ontology is not encoded in OWL (Mizoguchi, et al., 2007), thus it makes it difficult to reuse.

OWL is extremely rich in terms of being able to describe relations among classes, properties and individuals. In both the IMS-LD ontology and LOCO, OWL is used to define more complex properties of relations (that is, more than "is-a") among concepts such as disjoint, union, exhaustive, and many other mathematical relations such as inverse, symmetric transitive, etc. This enables the core concepts of

[5] The World Wide Web Consortium (W3C) is an international consortium where Member organizations, a full-time staff, and the public work together to develop Web standards (W3C, 2009).

instructional design, *Learning Objective*, *Method*, *Learning Object*, *Learning Design*, *Activity* and *Role* to be organised in taxonomies with new relations.

However, OWL has limitations in its ability to define the complex constraints, such as axioms (Amorim, Lama, Sanchez, et al., 2006). Axioms are used for representing the knowledge which has to be accepted without proof (Mizoguchi, 1998). In order to describe complex axioms in OWL, a new language, called Semantic Web Rule Language (SWRL), has been submitted to the W3C for consideration (Horrocks, Pater-Schneider, Boley, Grosof, & Dean, 2004). The other ontology language which has been used to define complex axioms in ontology, is Frame-Logic (F-Logic) (Amorim, Lama, Sanchez, et al., 2006). F-Logic is one of the traditional ontology languages; it has a sound and complete resolution-based proof procedure, which makes it computationally attractive (Kifer & Lausen, 1989).

Consideration of Learning Style

Learning style is considered to be one of the major determinants for learning personalisation (Karagiannidis & Sampson, 2004). Thus it is a crucial element for achieving the personlisation of instructional design. The IMS-LD specification currently only allows the inclusion of learner information, but including learning styles is a future possibility (Koper & Olivier, 2004). Consideration of learning styles for an ID ontology is found in the eLearning personalisation platform <e-aula>, which was designed by Sancho, Martínez, and Fernández-Manjón (2005). Since there are many learning style taxonomies, they suggest relating instructional designs to these various learning style models. Sancho et al. (2005) point out that the work of Ullrich (2004) and Meisel et al. (2003) on ID ontology failed to consider adaptation of teaching methods to different learning styles. One ID ontology that does relate instructional designs to learning styles is that developed by Arapi et al. (2007). Their ID ontology allows explicit specification of different teaching methods, coupled with the appropriate learning style, which in turn links to the taxonomies of learning styles. Arapi et al. suggest that following this approach would enable instructional strategies to be selected depending on the learners' preferred learning styles. Lastly, consideration of learning styles is also found in the OMNIBUS ontology (Mizoguchi, et al., 2007). Though the instructional designs for OMNIBUS are not clearly linked to any learning style taxonomy, they are able to be specified with learning styles and thereby allow greater personalisation of learning.

Consideration of Domain Knowledge

Specifying domain concepts in an instructional design contributes to the personalisation of instructional designs (Arapi, Moumoutzis, & Mylonakis, 2007). However, it also reduces the reusability of the instructional design as noted by Knight et al. (2006). Knight et al. (2006) suggest separating context information (which includes domain information) from instructional design ontology and including it in a separate ontology, which they developed and named Context Ontology. They believe that keeping the context information separate from instructional design would allow greater reusability of the instructional design. Van Marcke (1998) also agrees with this suggestion and considers that instructional design knowledge should be generic and re-applicable in completely different domains. However, he notes that the instructional design knowledge, in order to remain usable in a specified learning situation, should not be completely independent of the subject.

Domain knowledge could be specified in two places in an ID ontology. One of these places is the instructional design (Van Marcke, 1998); another is in the learning objects defined in the instructional design (Arapi, Moumoutzis, & Mylonakis, 2007). In the Arapi et al. (2007) ID ontology, domain concepts are specified for learning objects defined in an instructional design. They consider this would enable the learning objects to perform a certain learning activity to be delivered to the learner if the domain concepts are also specified in the learner's learning objectives. The OMNIBUS ontology developed by Mizoguchi, et al. (2007) supports the linking of learning objects into the learning scenarios it generates, but the ontology has yet to provide any function to link the learning objects to domain knowledge. However, this is planned for the future development of the ontology.

The Application of Instructional Theories

Instructional theories can be used to ensure the quality of instruction (Mizoguchi & Bourdeau, 2000). Instructional theories prescribe optimal methods of learning and instruction. Learning outcomes can even be improved if instructional design theories are applied in the creation of instructional designs (Merrill, 1999). Nevertheless, it has been noted by Reigeluth (1983) that instructional theories are usually difficult to use in practice because they are usually written in natural languages and use a different terminology. To enable the application of the instructional theories in eLearning systems Mizoguchi, et al. (2007) suggest interpreting instructional theories from an engineering point of view by encoding them in an ontology named OMNIBUS.

OMNIBUS ontology was proposed for modelling learning and instruction using various educational theories. It was developed from a working hypothesis that was based on Reigeluth's (1983) and Ertmer's (1993) consideration of commonality and difference among paradigms and theories. The working hypothesis of OMNIBUS ontology states that the idea of states in the learning process is common, though the assumed mechanism of developing knowledge is different for each paradigm (Mizoguchi, et al., 2007). Mizoguchi, et al. organised the educational theories and presented them as 'Way-knowledge' (educational strategies), which contributes to the design guidelines for modelling learning and the instructional design process so that the quality of instruction is assured.

The downside of the OMNIBUS ontology, as noted by Wang and Kim (2007), is that the teaching strategies in the ontology specify their Micro-events as "AND" or "OR" arcs, which does not imply any ordering constraints. In addition, all concept knowledge in the ontology is modelled as classes, so it omits a notion corresponding to OWL individuals. Future work suggested for improving OMNIBUS includes the integration of more learning theories and linking of instructional designs with domain knowledge and learner model (Hayashi, Bourdeau, & Mizoguchi, 2008). The OMNIBUS project website[6] points to future exploration of the properties of the ontology as well as work on understanding the relation between its attributes and learning object metadata. Currently, the authors have only defined attributes of learning and instruction in the ontology.

The Use of Ontology Axioms

Axioms in an ontology give semantic constraints among concepts along with rigorous definition of concepts (Mizoguchi & Bourdeau, 2000). Axioms is one of the modelling primitives of the common vocabulary of an ontology (Staab & Maedche, 2000). Gruninger and Fox (1995) point out that if an ontology does not include axioms, it does not constitute an ontology. Gruber (1995) underlines the importance of axioms for an ontology in the philosophy of coherence. Gruber states that an ontology should be coherent, and the axioms in the ontology help ensure the logical consistency of the defined concepts.

Both Lama, et al. (2005) and Mizoguchi, et al. (2007) propose the use of axioms

[6] http://edont.qee.jp/omnibus/doku.php

to ensure the logical consistency of the concepts defined in their ID ontologies. Lama, et al. (2005) developed axioms using F-Logic in their IMS-LD ontology, which include the design-related and run-time related axioms. These axioms in the ontology validate the logical consistency among the concepts of the IMS-LD as well as providing support for computational reasoning. Mizoguchi, et al. (2007) defined a number of axioms which are based on the educational theories in their OMNIBUS ontology. These axioms are used to validate the instructional design models against various educational strategies, thus ensuring pedagogically sound instructional design models.

The definition of axioms in an ontology may limit its applicability (Tankeleviciene, 2008). According to Tankeleviciene's (2008) definiton, an ontology is considered heavyweight if it includes axioms, and the ontology is considered to be more easily applied if it is lightweight. Thus, one limitation of the heavyweight ontology is it is narrow applicability. The OMNIBUS ontology has been regarded as heavyweight (Mizoguchi, et al., 2007), and in Wang and Kim's (2007) proposal for an Intelligent Tutoring System based on the OMNIBUS ontology, they point out that searching through OMNIBUS ontology is a heavy task without the aid of a smart authoring tool. This indicates the downside of implementing an ontology that includes axioms.

The Availability of an Authoring Tool

Each of the developed ID ontologies requires a compatible authoring tool to implement it. The developers of ID ontologies either have developed or are planning to develop authoring tools for their ontologies. The web authoring tool WebLD which supports the modelling, creation, validation and delivery of IMS-LD documents based on their IMS-LD ontology has been developed by Lama, Sanchez, Amorim, and Vila (2005). This authoring tool initiates three design strategies for the creation of instructional designs, and it automatically validates the elements of instruction designs against the axioms defined in the IMS-LD ontology. Mizoguchi, Hayashi, and Bourdeau (2007), who developed OMNIBUS ontology, proposed SMARTIES which is a theory-aware and IMS-LD standards-compliant authoring system. Based on the OMNIBUS ontology, it provides multiple theory-based guidelines for scenario design as well as theoretical justification for a scenario. That is to say, when the author uses SMARTIES to create an instructional design, she/he can choose a theory as a basis without the need to understand all the specifics of the chosen pedagogical theory and their implications for the instructional design. While the author creates a scenario with a particular strategy in mind, SMARTIES can also supports the author by finding similar theories corresponding to the strategy. Knight et al. (2006), who developed LOCO, are planning to develop tools to extend some of the present learning design editors (for example, Reload LD Editor) to support creation of LOCO-based learning designs, with the eventual goal of further evaluating their ontology (Knight, et al., 2005).

Summary

This chapter firstly investigated the shortcomings of eLearning systems, highlighting the lack of support for learning course authoring and personalisation. Then the discussion turned to how an ontology can address these limitations. By presenting various educational ontologies proposed for eLearning, the function and purpose of the ID ontology were examined. Purposes for the ID ontology include:

1. to increase the expressiveness of the instructional design in eLearning systems, and facilitate computational reasoning (Lama, et al., 2005);
2. to enable instructional designs to be more easily searched, shared and reused (Knight, et al., 2005);
3. to support automatic construction of personalized eLearning experience (Van Marcke, 1992);
4. to support the creation of pedagogically sound instructional designs (Mizoguchi & Bourdeau, 2000).

This review demonstrates that the use of ontology contributes to the development of instructional design, though the current literature indicates that an ID ontology is difficult to develop. Nevertheless, while Mizoguchi and Bourdeau (2000) are proposing to identify the minimal agreement for the design of an ID ontology, this review found that researchers have expressed various views regarding the crucial challenges facing development of an ID ontology. These key issues include:

1. whether or not to use concepts hierarchy to improve the reusability of instructional designs;
2. selecting the appropriate language for developing an ID ontology;
3. the need to develop an ID ontology with learning standards in mind;
4. whether ID ontology needs to be related to learning styles;
5. whether ID ontology needs to be related to domain knowledge;
6. the challenges of applying instructional theories in an ID ontology;
7. the need to use axioms in ID ontology;

8. the availability of authoring tools (based on the ontology).

None of the researchers have considered these issues in an integrative way to evaluate the developed ID ontologies. The issues identified in this review will be used to construct the framework that could inform the development of an ID ontology.

CHAPTER 3 METHODOLOGY AND PROCEDURES

This chapter describes the method applied in this research and the rationale for using it. Also, the steps of this research as framed by the method are elaborated. The ethical issues involved in the study are discussed. Finally, the research design limitations of this study are outlined.

Methodology

Research Purpose

The goal of this research is to identify the crucial elements necessary for a *quality* ID ontology. Based on a synthesis of these crucial elements, a framework will be developed. Such a framework would provide practitioners with a guideline for evaluating the *quality* of an ID ontology. The term 'quality' used in this research, as previously defined in the Chapter 1, means an ID ontology is required to have certain characteristics that satisfy its intended purposes and functions. These, as found through the literature review, are:

1. to increase the expressiveness of the instructional design in eLearning systems, and facilitate computational reasoning (Lama, et al., 2005);
2. to enable instructional designs to be more easily searched, shared and reused (Knight, et al., 2005);
3. to support automatic construction of personalized eLearning experience (Van Marcke, 1992);
4. support the creation of pedagogically sound instructional designs (Mizoguchi & Bourdeau, 2000).

In particular, the review of literature also reveals that scholars have identified the following issues in relation to ID ontologies fulfilling these intended purposes:

1. whether or not to use concepts hierarchy to improve the reusability of instructional designs;
2. selecting the appropriate language for developing an ID ontology;
3. the need to develop an ID ontology with learning standards in mind;
4. whether ID ontology needs to be related to learning styles;
5. whether ID ontology needs to be related to domain knowledge;
6. the challenges of applying instructional theories in an ID ontology;
7. the need to use axioms in ID ontology;

8. the availability of authoring tools (based on the ontology).

Epistemology

All research should possess an epistemological foundation, since it is the underlying assumptions about what makes a valid research and to evaluate which research methods are appropriate (Orlikowski & Baroudi, 1991). According to Chua (1986), there are three classifications of research epistemology: positivist, interpretive and critical studies. Positivist research mainly aims to test theory, “in an attempt to increase predictive understanding of phenomena”, whereas interpretive research “attempts to understand phenomena through accessing the meanings that participants assign to them” (Orlikowski & Baroudi, 1991, p. 5). More than either the positivist or interpretive research, critical research “attempts to critically evaluate and transform the social reality under investigation” (Orlikowski & Baroudi, 1991, p. 19).

The interpretive stance was considered most appropriate because this research tries to identify the crucial elements for evaluating ID ontology from the quality point of view. Another justification for the interpretive epistemology is the need to understand why these elements are crucial when considering the goals that an ID ontology is aiming to meet. In addition, the interpretation of reasons that the current ID ontologies were developed with their individual foci was also provided in this research, for example, interpretation of the reasons for ID ontology developers relating learning styles and domain knowledge to their particular ontology.

Qualitative Research Approach

A qualitative approach was adopted in this research which involved using both meta-ethnography and analyst triangulation methods. The reason for employing the qualitative approach is that a review of the literature showed that while no studies consider the crucial elements for an ID ontology from the quality point of view, there are studies that have discussed the general purposes of an ID ontology. Since the qualitative research approach is found to be especially suitable for the investigation of topics that have not been previously researched (Orlikowski & Baroudi, 1991), it seemed appropriate to adopt this approach for this research. Further, the researcher tries to understand the crucial elements associated with the quality of ID ontology, rather than testing these.

As described in Chapter 1, the reason for synthesising the crucial elements identified from each ID ontology is that it is believed that analysis of several developed ID ontologies could allow for interpretation beyond the scope of any single ID ontology. This, in turn, would inform the development of ID ontologies and contribute to a quality ID ontology that meets the needs of both learners and instructional design authors. In addition, each of the ID ontologies investigated in this study was not built upon the other ontologies, which implies that the crucial elements included by their developers have not been brought together or compared, that is to say, synthesised. Regarding the term synthesis used in this research, this research adopted the definition of Strike and Posner (1983, p. 346), who note that "[s]ynthesis is usually held to be activity or the product of activity where some set of parts is combined or integrated into a whole". Thus, the crucial elements (or "parts") of the ID ontologies are examined, identified and combined into a framework.

Meta-Ethnography

This research was framed by the meta-ethnography method. Meta-ethnography is an interpretive approach originally developed by Noblit and Hare (1988) for synthesising the findings of ethnographic research conducted in the field of education. By using the prefix *meta* the researchers are emphasising their "intent to focus on the synthesis enterprise" (Noblit & Hare, 1988, p. 13). Such a method has recently been used for synthesising the findings across qualitative research in the field of public health. Both Campbell et al. (2003) and Atkins et al. (2008) conducted a feasibility study on health research to demonstrate that qualitative research papers can be successfully synthesised using the meta-ethnography method. The authors believe this method results in a greater degree of insight and conceptual development. Savin-Baden (2007) used meta-ethnography in higher education research to synthesise six qualitative studies in the area. He concluded that meta-ethnography is a very useful method in terms of comparing different qualitative studies and constructing interpretations.

Why meta-ethnography was applied. The meta-ethnography approach was considered an appropriate research framework for this study for two reasons. First, meta-ethnography seemed to be an applicable method for synthesising the studies identified for this research, since the studies identified for each ID ontology are treated as individual case studies. Noblit and Hare (1988) not only claimed that meta-ethnography is used for synthesising findings across ethnographic studies, but they also suggested that the method is appropriate for synthesising the findings across any qualitative study, including case studies (Noblit & Hare, 1988). Case study is one of the most common approaches applied in the Information Systems field (Alavi, 1992), and it has been used by most ID ontology developers to investigate and guide the implementation of their developed ID ontologies. The authors of the IMS-LD ontology, Sanchez, Lama, Amorim, Vidal, and Novegil (2008) describe in their papers how the Astronomy case study is modelled, created and executed using the IMS-LD ontology. Arapi, Moumoutzis, Mylonakis, Stylianakis, and Theodorakis (2007) demonstrated how their ID ontology was used in LOGOS platform[7] to support the creation of abstract training scenarios. The merit of abstract training scenarios is that the learning objects are not bound to the training scenarios at design time as in current eLearning standards and specifications, but the learning objects are selected according to a learner profile at system run-time to deliver a real personalised experience to the learner (Arapi, Moumoutzis, Mylonakis, et al., 2007). The authors of OMNIBUS ontology, Mizoguchi, et al. (2007) explained in their paper how all the merits of the OMNIBUS ontology can be utilised computationally and conceptually in an authoring system named SMARTIES.

As demonstrated, each of the ID ontologies investigated in this study was firstly developed and then implemented in one or more compatible authoring systems to evaluate if the intended purposes were being met. Finally, the findings for each of the ID ontologies were reported effectively in one or more papers, which were the studies selected for synthesising in this research. Therefore, the studies identified for each of the ID ontologies could be treated as individual case studies in this study, and so be dealt with according to the meta-ethnographic method.

The second reason for applying meta-ethnography was that it provided a useful framework for guiding the synthesis of the crucial elements of ID ontologies. The elements were drawn from each ontology, yet retained the original meaning of the element in the context of the specific ID ontology. Weed (2005) considered that meta-ethnography provided an appropriate research framework for synthesising findings across qualitative studies while retaining the original meaning of each study. All qualitative studies focus on “meaning in context” (Mishler, 1979, p. 7), thus it is important that the meaning in context is retained after synthesis (re-interpretation). As noted by Bryman and Bell (2007), meta-ethnography primarily focuses on the interpretation and explanation offered by studies that are included, rather than on the data on which these studies are based. Therefore, the “meaning in context” will not be

[7] The LOGOS platform is a learning platform that includes all functionalities to create and deliver personalised learning experiences (Arapi, Moumoutzis, Mylonakis, et al., 2007).

easily lost by using meta-ethnography.

Seven phases of the meta-ethnography approach. According to Noblit and Hare (1988), meta-ethnography involves a series of seven phases as the synthesis progresses; it provides a step-by-step program that will allow the researcher to show similarity (‘reciprocal translation’), or difference (‘refutation’) among selected studies. The phases are:

- Phase 1 - “Getting started” (Noblit & Hare, 1988, p. 26). This step involves determining a research question that could be informed by qualitative research (Bryman & Bell, 2007). In particular, this step is about finding something that is “worthy of the synthesis effort”.
- Phase 2 - “Deciding what is relevant to the initial interest” (Noblit & Hare, 1988, p. 27). Once the research question is determined, a decision is made regarding what accounts are likely to be credible for the research. This step also includes searching relevant studies and including those eligible by using the inclusion criteria.
- Phase 3 - “Reading the studies” (Noblit & Hare, 1988, p. 28), which means repeated reading. This requires extensive attention to the details of the included studies.
- Phase 4 - “Determining how the studies are related” (Noblit & Hare, 1988, p. 28). This step requires determining the relationships between the studies to be synthesised by creating a list of the key concepts, themes, ideas used in each study and juxtaposing these.
- Phase 5 - “Translating the studies into one another” (Noblit & Hare, 1988, p. 28). This step implies comparing the concepts in one study with the concepts in others. There are two methods suggested for this comparison. One method is called ‘reciprocal translation’ which involves the comparison of concepts across studies and an attempt to match concepts from one study with concepts from another. However, when there are studies about different things so that the assumption of similarity is not reasonable, another method called ‘refutational synthesis’ is suggested.
- Phase 6 - “Synthesising translations” (Noblit & Hare, 1988, p. 28). This step involves putting any similarities and dissimilarities between studies into an interpretive order, which helps to explain and infer the relationships between

the concepts. Also, this step involves giving explanation if reciprocal translations suggest a lack of congruence after the concepts are compared across studies.

- Phase 7 **-** "Expressing the synthesis" (Noblit & Hare, 1988, p. 29). Here, all the similarities and dissimilarities are put together as a whole, in order to make the results easily accessible to a wide audience. This step involves creating symbolic form for expressing synthesis for practitioners.

These seven phases have been adopted for guiding the synthesis of the crucial elements necessary for a quality ID ontology.

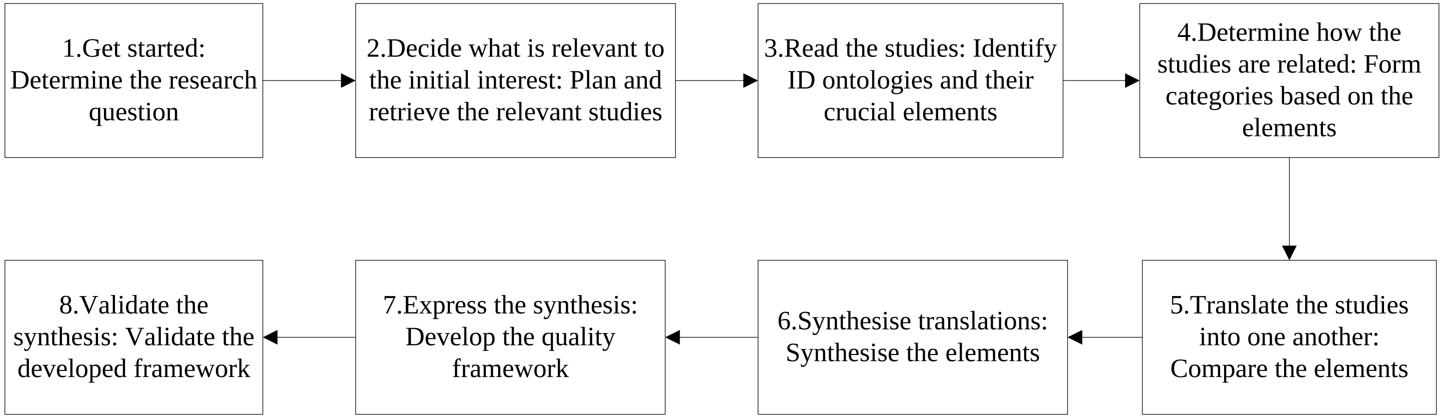
Analyst Triangulation

Analyst triangulation was used to ensure the accuracy of the findings for this research. It is one of the four kinds of triangulation strategy that contribute to validation of qualitative analysis and involves using two or more subject experts to independently review findings (Patton, 2002). As Walsh and Downe (2005) point out, the meta-ethnography synthesis method is in its infancy, so there has been no technique suggested regarding how to ensure the soundness of analysis. Therefore, analyst triangulation was considered appropriate because it helped ensure the credibility of the research findings.

Procedures

This section reports how meta-ethnography framed this study in synthesising the crucial elements associated with the quality of ID ontology. The seven phases suggested within the meta-ethnography method are used to identify the eight steps of the research design (see Figure 1), and the following paragraphs elaborate these steps.

Figure 1. Research process framework



Step 1: Determine the Research Question

The research question was decided after conducting the initial literature review. However, to ensure the value of the synthesis effort for the intended audiences, the researcher emailed eight experts[8], identified from the website of the International Workshop on Ontologies and Semantic Web for E-Learning (http://compsci.wssu.edu/iis/swel/index.html). A description of the research and purpose was provided and the experts were invited to comment and give their opinions as to the merit of the synthesis results. In addition, some of the ID ontology developers were also contacted to clarify the researcher's understanding of a particular aspect of their work or to answer any specific query the researcher had. Eighteen ID ontology developers were contacted: nine developers replied within three days, two replies within a month, and seven developers did not respond at all. After consulting with both the developers and experts, the research question was then finalised and the research value confirmed.

Step 2: Plan and Retrieve the Relevant Studies

Once the research question was formed, meta-ethnography suggests retrieving the relevant studies. The method does not specify in detail how to retrieve the relevant studies or give guidance on inclusion and exclusion factors relating to the studies. However, as explained by Bryman and Bell (2007), unlike quantitative reviews, qualitative reviews are not concerned with developing an exhaustive list for studies that might be included in the review. Thus the researcher only took into account the studies found to be relevant for the findings of the research. The inclusion criteria were developed and included any studies which:

1. discussed the development of an ID ontology;
2. reported the findings for the implementation of a particular ID ontology;
3. discussed the eLearning ontologies in general.

Both published and unpublished studies[9] reported in English were considered. Because of resource limitations, papers published in other languages were not considered.

In order to locate relevant studies, search terms were developed by the researcher based on the initial review of the literature. These search terms were "(learning OR instructional) AND design AND ontology". They were used in five

[8] Experts are defined as the people who had researched instructional design in the area of ontological engineering for more than five years.

[9] All the unpublished studies were obtained directly from the authors.

search engines which include IEEE, Proquest, Science Direct, Web of Science, and EBSCO. The search was complemented by reviewing citations, searching in Google Scholar, and referrals from the experts. In addition, there were two websites primarily used for this research: Ontology for Education (O4E) (http://o4e.iiscs.wssu.edu/xwiki/bin/view/Main), which is a community site which includes a collection of O4E related articles and commentaries, and the website of the International Workshop on Ontologies and Semantic Web for E-Learning (http://compsci.wssu.edu/iis/swel/index.html). From these two websites, the researcher identified some important studies relating to eLearning ontologies and the key researchers in the field.

There are 170 relevant studies that were identified in the various databases and the other Internet sources, brief details of which are presented in Table 1.

Table 1. *Review of Source Selection*

Source title	Review start date	Review end date	*n* papers
Conference proceedings (various)	2002	2008	62
Advanced Technology for Learning Journal	1983	2008	12
Canadian Journal of Learning and Technologies	1983	2008	4
Journal of Educational Technology & Society	1983	2008	23
International Journal of Artificial Intelligence in Education	1983	2008	25
International Journal of Continuing Engineering Education and Lifelong Learning	1983	2008	15
Journal of Interactive Learning Research	1983	2008	9
Journal on Interactive Media in Education	1983	2008	20
Total Papers			170

Based on the inclusion criteria set, approximately 30% (n = 57) of the studies were not considered eligible after the title and abstract were reviewed by the researcher. Further, it was found that some journal articles reported findings that were similar to some of the conference papers selected and the journal articles reported the findings in more detail. Therefore, nine duplicate conference papers were excluded and 104 papers were considered eligible for the study.

Step 3: Identify ID Ontologies and Their Crucial Elements

In this step, meta-ethnography suggests identifying similar key concepts, and features between studies by reading them in detail. Firstly, all the studies identified were grouped according to the ID ontology they discussed. Then, after reading and understanding each of the studies in detail, and based on the definition of ID ontology given in this research, that is, the ontology that formally represents knowledge about the teaching and learning process (Paquette, 2003), four ID ontologies in total were selected from the included studies. The ID ontologies with their key features were listed in a table for later comparison. Once all the information on ID ontologies was reviewed, the researcher began to identify the elements from the studies which were considered as crucial by the ID ontology developers. The developers consider the elements to be crucial for an ID ontology by demonstrating how the individual element helps meet the intended purposes and functions of an ID ontology. Most of these elements were found in the Introduction section of the relevant study. The researcher summarised the information about the identified elements and noted the context of the relevant research in a standard form suitable for the later comparison step. The task of identifying the crucial elements was not finished until the end of the synthesis effort, since the list of the crucial elements was developed throughout the research and not complete until the end of the research period.

Step 4: Form Categories Based on the Elements

The researcher inductively formed categories from all elements identified in the previous stage as being important in the development of a quality ID ontology. There were four categories identified as closely relating to the quality of an ID ontology: Reusability, Personalisation, Quality assurance, and Applicability. The categories reusability and personalisation had already been mentioned in other studies, however, quality assurance and applicability were categories formed by the researcher.

Step 5: Compare the Elements

Following the meta-ethnography method, this step involves comparing each of the crucial elements considered in one ID ontology with those in the other ontologies, ensuring that the elements identified are captured across the ID ontologies. This was done by following the ‘reciprocal translation’ approach, which suggests comparing identified concepts in each study with the other studies that include similar concepts (Noblit & Hare, 1988). Since the order in which studies are compared may influence the resulting synthesis (Atkins, et al., 2008), the researcher started with a ‘classic’ ID ontology identified by one of the experts in the field. Where there are elements unique to one ID ontology but absent from the others, they were treated as separate elements to be considered for synthesis in the later stage. The reason for doing this was because explicit refutation has considerable potential for promoting reflexivity and enriching the human discourse (Noblit & Hare, 1988). Noblit and Hare (1988) explain refutation as the observation of difference which may help identify opinions that have been insufficiently considered. An example of this is the element 'the application of instructional theories', which is unique to the OMNIBUS ontology but absent from the other ID ontologies, thus impeding direct comparison. This element was analysed substantively and subsequently incorporated into the synthesis. Use of instructional theories for instructional design is still in the trial stage (Hayashi, et al., 2008), but it reveals the importance of integrating pedagogical knowledge in an ID ontology, thus a new element 'integration of pedagogical knowledge', which represents the application of educational theories for instructional design, was presented and incorporated into the synthesis.

Step 6: Synthesise the Elements

After all the elements were compared across ID ontologies, the researcher listed all elements in a logical order, including those that were common and unique. Then the elements were ordered according to their purpose and the stage in the development of the ID ontology at which they need to be considered, that is, modelling, validation or execution stage.

Step 7: Develop the Quality Framework

Once the identified elements were synthesized, it was decided to present the synthesis in a simple diagrammatic form. This form was considered suitable for the reader with a background in ontology. The framework was thus finally formed by integrating all the necessary identified elements for evaluating the quality of an ID ontology.

Step 8: Validate the Developed Framework

After the crucial elements associated with the quality of the ID ontologies were synthesised and expressed in a diagrammatic form, the researcher selected two experts in the field to review the framework, particularly with regard to the intended purposes and functions identified for a quality ID ontology. The criteria for selecting the experts were: either a person who had developed a workable ID ontology, or a person who had researched instructional design in the area of ontological engineering for more than five years. The two experts were asked not only to validate the framework, but also to check if the integrity of each selected ID ontology was intact following the meta-ethnography process. Presumably, this would enable them to pass judgment on whether the crucial elements considered in respect of the relevant ID ontology were accurately interpreted. The feedback received from the experts was reviewed and incorporated into the original framework and then sent out to them for a further review. Finally, they both confirmed the accuracy of the framework.

Ethical Considerations

In the initial research phase, this project was peer-reviewed by the supervisors. Based on the Massey University Low Risk Guidelines, it was concluded that the project was low risk. As such, this project was reported to the Massey University Human Ethics Committees on 16 February, 2009 and recorded on their Low Risk Database.

As mentioned earlier, the researcher had email contact with the ID ontology developers and some experts in the field. All correspondence between the researcher and contacts was on a voluntary basis. The purpose of these contacts was also made clear in each of the emails sent by the researcher. In addition, the emails provided basic information about the researcher, background to the study, and so on. The two experts who consented to validate the framework were sent an information sheet stating the context and purpose of the research, basic information about the researcher, their rights regarding their participation in and contribution to the research and the framework. Each expert's identity and comments, received in relation to the evaluation, were treated in strictest confidence. Any identifiable characteristics of the participants in this study or their institutions were not disclosed in any of the written reports produced in the course of this research.

Limitations

Four limitations in terms of the research design were identified in this study. The first limitation relates to the analysis method. Since the researcher inductively formed categories by considering the crucial elements identified from the literature, all the categories and names emerged from the data rather than there being preconceived categories. One challenge in doing this is developing a complete understanding of the context, and so the potential failure to identify key categories (Hsiu-Fang & Sarah, 2005). Lincoln and Guba (1985) suggest the risk could be minimised by applying analyst triangulation, thus it was employed in this research to ensure the reliability and validity of the findings.

The second limitation concerned the limited information that may be available for ID ontologies. A risk was that the crucial elements of each ontology may not be correctly analysed since most of the papers reviewed only stated the ontologies in outline. To mitigate this, the researcher downloaded each of the ID ontologies from the respective project websites, and thoroughly analysed them.

The third limitation is implied by the nature of any qualitative synthesis research, which is the reliability and validity of the synthesis. It is possible that any outcome of qualitative synthesis which may be influenced by the researchers (Atkins, et al., 2008), thus the issue of reproducibility of the synthesis is an area which could have been examined further. However, time constraints meant that this aspect could not be addressed in this research and future studies may address this.

The fourth limitation relates the use of the meta-ethnography approach. As Walsh and Downe (2005) pointed out, meta-ethnography is still in its infancy, and its processes are ill-defined. In particular, the process of retrieving relevant studies does not state how the eligible studies should be selected. Though the inclusion criteria developed in this study for identifying eligible studies may limit the findings of synthesis, it could be assumed that such risk was mitigated by having the inclusion criteria in this research validated by experts.

The next chapter presents the framework, developed from examination of the literature review. The four categories and their associated elements considered necessary for a quality ID ontology are identified and discussed.

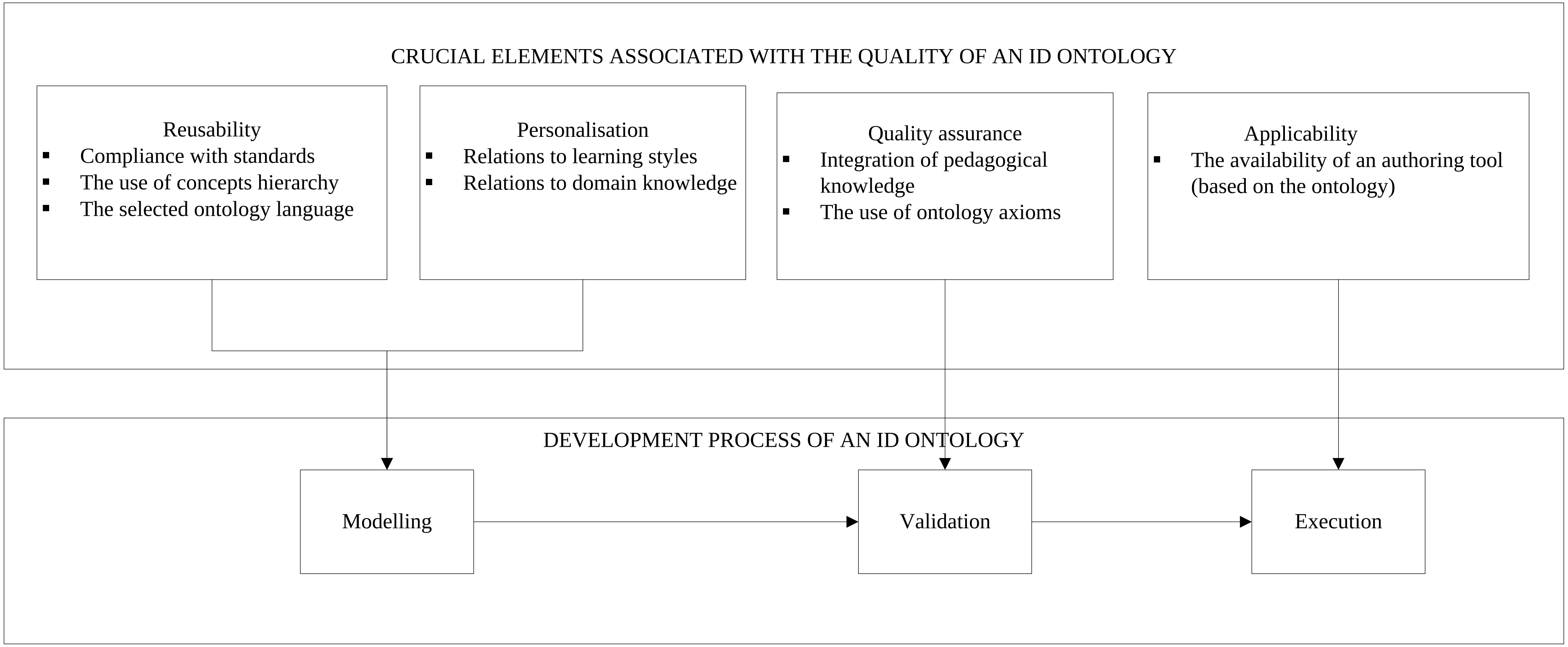
CHAPTER 4 DEVELOPMENT OF THE FRAMEWORK

This chapter describes the framework developed in this study for evaluating the quality of ID ontologies. The framework is presented first, and then each of the identified categories and crucial elements of the framework are discussed. Finally, the feedback received from the experts regarding the developed framework is reported.

The Framework

Through a synthesis of the crucial elements considered in different ID ontologies, a framework was formed for evaluating the quality of ID ontologies. The framework is depicted in Figure 2. The four main categories of Reusability, Personalisation, Quality assurance, and Applicability are shown in relation to the eight crucial elements. The elements and the categories are also depicted in relationship to stages in the development process for an ID ontology. These stages, Modelling, Validation and Execution are considered necessary by Sanchez, et al. (2008) for creating an ID ontology.

Figure 2. The framework for evaluating the quality of an ID ontology



As shown in Figure 2, Reusability and Personalisation of instructional designs should be taken into account in the Modelling stage of the development of an ID ontology. Reusability involves the consideration of using concepts hierarchy, selecting an appropriate ontology language, and compliance with standards. Personalisation involves consideration of relating the ID ontology to both learning style and domain knowledge. In the Validation stage of the development of an ID ontology, the mechanisms for assuring the quality of the developed instructional design model are considered. This involves the integration of pedagogical knowledge such as educational theories, and the use of ontology axioms to detect the logical consistency between concepts. Lastly, the Execution stage concerns the applicability of the ID ontology, which could be proved (demonstrated) through an authoring tool based on such an ontology.

The following sections outline how the elements shown in the framework were selected, the rationale for considering them as crucial elements is discussed, and each of the categories formed, based on these elements, are discussed.

Selection of the Elements

The elements considered as crucial for developing a quality ID ontology were selected based on consideration of the intended purposes and functions that a quality ID ontology should satisfy. This selection was based on the definition of 'quality' given in Chapter 1, that is, a high quality ID ontology is required to have certain characteristics that satisfy its intended purposes. These requirements, described in Chapter 2, are:

1. to offer increased expressiveness of the instructional design in eLearning systems, and facilitation of computational reasoning (Lama, et al., 2005);
2. to enable instructional designs to be more easily searched, shared and reused (Knight, et al., 2005);
3. support automatic construction of personalized eLearning experience (Van Marcke, 1992);
4. to support the creation of pedagogically sound instructional designs (Mizoguchi & Bourdeau, 2000).

The elements were identified from an examination of four ID ontologies. The ID ontologies were selected according to the definition given in Chapter 3, that is, an ontology that formally represents knowledge about the teaching and learning process

(Paquette, 2003). Brief details of the selected ID ontologies are listed in Table 2.

Table 2. *Development Background Details of the Four ID Ontologies*

Development Background	ID Ontology			
	IMS-LD ontology	LOCO	ID ontology_Arapi et al.	OMNIBUS
The ontology developers	Lama, Sanchez, Amorim, Vila	Knight, Gašević, Richards	Arapi, Moumoutzis, Mylonakis	Mizoguchi, Hayashi, Bourdeau
Year developed	2005	2005	2007	2007
Construction tool	Protégé	Protégé	Unknown	HOZO
The time the ontology had been in development	< 1 year	< 1 year	Unknown	7 years
The person-years spent in developing the ontology	5	3	5	3

Note. ID ontology_Arapi et al. is the name given in this research to distinguish the ID ontology of Arapi et al. from the other ID ontologies.

As shown in Table 2, the first ID ontology was developed in 2005, and the other two ontologies were developed in 2007. Most of them were developed using Protégé editor. The OMNIBUS ontology was develoepd by the authors' own development tool named HOZO. OMNIBUS ontology took seven years to complete since it translated 100 educational theories into the ontology. Both IMS-LD and LOCO ontologies took less than a year to develop because they started from an existing conceptual model (IMS-LD Information Model) and formalized this into ontology. In other words, they did not have to go through the laborious tasks of literature analysis, identification of relevant concepts and their relationships, and so on.

Description of the Elements

The crucial elements included in the framework are:

1. compliance with standards;
2. the use of concepts hierarchy;
3. the selection of ontology language;
4. relations to learning styles;
5. relations to domain knowledge;
6. integration of pedagogical knowledge;
7. the use of ontology axioms;
8. the availability of an authoring tool (based on the ontology).

These elements were compared across the four ID ontologies, the details of which are shown in Table 3.

Table 3. *Comparison Matrix Crucial Elements*

	ID ontology			
Crucial elements	IMS-LD ontology	LOCO	ID ontology_Arapi et al.	OMNIBUS
Does the ontology include any concepts hierarchy?	Yes, including the reference class *Item* to learning object, the class *Execution Entity*, and the *Completion Unit*	Yes, including the reference class *Resource Description* to learning object, *the class Abstract Activity* and the *Completion Requirement*	Not available	Yes, many
What modelling language has been used for the ontology?	OWL, F-Logic, SWRL (planned)	OWL	OWL	HOZO, OWL
Was the ontology developed based on learning standards?	IMS-LD	IMS-LD	IMS-LD, LOM	IMS-LD
Is the ontology related to learning style?	No	No	Yes	Yes
Is the ontology related to domain knowledge?	No	No	Yes	Currently no but planned to do
Does the ontology integrate any pedagogical knowledge?	No	No	No	Yes, educational theories
Does the ontology have axioms?	Yes, expressed in F-Logic (design and runtime related)	No	No	Yes, expressed in HOZO (theory related)
Have the ontology got any authoring tool available? Is it user-friendly?	WebLD, the usability is currently being improved.	Not available, but as the authors suggested, they planned to develop (LOCO-Analyst project, 2009)	Learning Design Editor in LOGOS; usability is to be tested	SMARTIES; usability is to be tested

As shown in Table 3, three out of four ID ontologies proposed abstract classes by taking advantage of an ontology language. Though OWL (the standard ontology language for the Semantic Web) was used as the common language for developing ID ontologies, other languages such as HOZO and F-Logic have also been used. As shown, the IMS-LD ontology was also modelled in F-Logic and OMNIBUS was also presented in HOZO. All the four ID ontologies took into account the IMS-LD specification. Further, two ontologies (ID ontology_Arapi et al. and OMNIBUS) relate to learning style and domain knowledge. Pedagogical knowledge has not been integrated in most ID ontologies except OMNIBUS which uses educational theories as a kind of pedagogical knowledge. Ontology axioms were applied in two ontologies (IMS-LD and OMNIBUS) which makes them more complex than the other two. Most of the ID ontologies developed to date have authoring tools for their implementation. Whilst LOCO presently has no authoring tool, one is planned in further development (LOCO-Analyst project, 2009).

The following sections describe each of the elements and the rationale for considering them as crucial for a quality ID ontology.

Compliance with Standards

Most ID ontologies allow the generation of standards-compliant instructional design models (that is, the IMS-LD compliant instructional design model). Both IMS-LD ontology and LOCO were developed based on a direct translation of the IMS-LD specification, thus enabling easy translation into its original modelling language, XML-Schema format. Amorim, Lama, and Sanchez’s (2006) work on IMS-LD ontology demonstrates that the validated instructional design documents via the IMS-LD ontology can be translated into the XML-Schema format. This enables the developed instructional design model to be executable in any IMS-LD-compliant system or tool. Although there has not been a specific authoring tool developed for LOCO, it is reasonable to assume that LOCO would allow the generation of an IMS-LD compliant instructional design model because it was developed strictly based on the IMS-LD specification. OMNIBUS ontology assures pedagogical soundness of the developed instructional design models but also it supports the generation of IMS-LD compliant instructional design models, since it aims to enhance the educational justification of standards-compliant contents (Mizoguchi, et al., 2007). Based on the evidence found in the three ID ontologies, ‘compliance with standards’ was thus considered as one of the crucial elements relating to the quality of an ID ontology.

Compliance with learning standards for an ID ontology is important because it allows the developed instructional design models to be read by any standards-compliant delivery system such as learning (content) management systems. IMS-LD enables the reuse and exchange of instructional designs between eLearning systems (Koper & Olivier, 2004), but it does not allow the definition of the semantic constraints between its concepts, which implies the possibility of an invalid instructional design (Amorim, Lama, Sanchez, et al., 2006). However, an ID ontology could be used for the validation of the specified concepts in an instructional design. Nevertheless, before an ID ontology that is IMS-LD compliant can be widely accepted by current eLearning systems, it is important that the developed instructional design models via ID ontology be translatable into the IMS-LD XML-Schema format. This would mean that the validated instructional design could be reused and exchanged between different eLearning applications.

Another reason to make an ID ontology compliant with IMS-LD specification is that doing so would enable the ontology to express any kind of pedagogical knowledge models. IMS-LD specification, which resulted from a number of years of instructional design research, is regarded as the de facto standard for instructional design. It has proved to be adequate as a means of describing any kind of pedagogical knowledge models (Koper, 2004). Therefore, selecting the IMS-LD as the basis for developing an ID ontology would imply that the ontology is capable of expressing any kind of pedagogical model, which would ensure the usability of the developed ID ontology.

The Use of Concepts Hierarchy

The use of abstract classes was found by investigating the information models of the four ID ontologies. For example, IMS-LD ontology introduced *Item* class for bridging the *Learning Design* and *Learning Object* class, which includes the subclasses *Activity Description*, *Prerequisite*, *Learning Objective*, *Feedback Description*, *Learning Object* and *Information*. *Execution Entity* class includes the subclasses *Activity* and *Activity Structure*. Similarly, LOCO ontology introduced the *Resource Description* class for bridging the *Learning Design* and *Learning Object* classes, which includes the subclasses *Activity Description, Prerequisite*, *Learning Objective, Feedback Description,* and *Learning Object*. Also, the *Completion Requirement* class includes the subclasses *Complete Unit*, *Complete Play*, *Complete Act*, and *Complete Activity*. The existence of the abstract class seems to be necessary in an ID ontology, thus it is recommended that the use of concepts hierarchy be one of the crucial elements that need to be considered in developing a quality ID ontology.

By proposing abstract classes the advantage of the inheritance and subsumption mechanisms is realised, thereby improving the structure of the instructional design. Currently, the desired learning objects for performing a learning action are usually specified in the instructional design object but the reusability of instructional design is very limited. With abstract classes such as the *Item* in the IMS-LD ontology and *Resource Description* in LOCO ontology, instructional designs are more likely to be reused because the links to learning objects are indirectly established through the *Item* or *Resource Description* class rather than the instructional designs themselves.

The Selected Ontology Language

It is noted that the Web Ontology Language (OWL) has been used as the common modelling language for developing the four ID ontologies investigated in this study. Since there has been a particular focus of concerns in the literature regarding the suitability of ontology language for developing an ID ontology, the selected ontology language is considered to be one of the crucial elements for developing a quality ID ontology.

OWL was chosen as the modelling language for the ID ontologies developed because it is the standard ontology language for the Semantic Web as proposed by the W3C (Dean & Schreiber, 2004). OWL facilitates the interoperability between different eLearning systems because it has the advantage of expressiveness compared with the other ontology languages which do not have this attribute. It is extremely rich in terms of being able to describe relations among classes, properties and individuals (Lama, et al., 2005). However, examination of the ontologies shows that OWL currently does not provide support for the definition of further constraints such as axioms. While the axioms are considered as the necessary components for developing an ontology (Gruninger & Fox, 1995), the other ontology languages may be employed to define axioms, such as the F-Logic that was introduced in the IMS-LD ontology and which was used to formally define the constraints for the IMS-LD related concepts in the ontology. The above discussion indicates that the selection of an appropriate ontology language is a crucial element in the development of a quality ID ontology.

Relations to Learning Styles

For achieving greater eLearning personalisation, relating instructional design to learning styles is considered by many ontology developers to be important. Arapi et al. (2007) suggest using the taxonomy of learning styles in their ID ontology, whereas Mizoguchi, et al. (2007) specify the suitable learning style for each of the training scenarios in their OMNIBUS ontology, though these training scenarios are not yet linked to any learning style taxonomy. Consideration of learning style was not found in either the IMS-LD or the LOCO ontology. Since consideration of a student's learning style could contribute to learning personalisation, it is considered worthwhile to relate ID ontology to learning styles.

The relation of an ID ontology to learning styles may be preferred when there is a particular focus on learning personalisation, and when each of the instructional design strategies is selected according to the learning style of the individual. While many taxonomies of learning styles have become available, they can be linked with any ID ontology (Sancho, et al., 2005). By linking with learning style taxonomy, it is possible for each instructional strategy to be automatically selected and processed at system run-time (not at design time) depending on the learners' preferred learning styles.

However, it has been suggested that the influence of learning style on learning outcomes is difficult to evaluate, This is partly due to the problem in separating the learning style from other factors that influence the learning process (Neuhauser, 2002). Therefore, although it is possible to develop a teaching strategy that caters for most learning styles (Riding, 1998), it is questionable whether the learning (eLearning) would be improved to such a degree that would make it worth the effort. An example is the ontology that describes the instructional roles of learning objects, developed by Ullrich (2004). It proposes the use of pedagogical ontologies to capture instructional design knowledge in a learning object. However, it does not enable the instructional knowledge to be specified according to any learning style model. In other words, Ullrich did not consider that the instructional designs for eLearning were improved through relating them to learning styles. Another example is the exemplary instructional design ontology proposed by Meisel, Compatangelo, and Hörfurter (2003) which recognises the need for supporting different training methods for the same subject, but does not take into account the different learning styles of those being trained. Therefore, since it is difficult to evaluate the effect of learning style on learning outcome, ultimately, the decision to relate the instructional strategy with learning styles may depend on the user's expectation of a personalised learning experience. Nevertheless, the discussion above indicates relation of learning style to ID ontology is worthy of inclusion as another crucial element in the development of a quality ID ontology.

Relations to Domain Knowledge

Domain knowledge includes the concepts of a subject domain and their relationships (Gascuena, et al., 2006). Its relation to instructional design is evident in the ID ontology developed by Arapi et al. (2007). Mizoguchi, et al. (2007) plan to link domain knowledge in their future work on the OMNIBUS ontology. However, linking to domain concepts is not mentioned in either the IMS-LD or the LOCO ontology. One possible reason is that the two ontologies are based on IMS-LD through a direct translation of the modelling language from XML-Schema to OWL. Since the IMS-LD specification does not suggest any relation to domain concept (Koper & Olivier, 2004) and they accepted the IMS-LD as the de facto standard for instructional design, they developed ID ontology without introducing any new concepts to extend the current IMS-LD specification. Nevertheless, it is recommended that instructional designs should relate to their domain knowledge.

The reason for this recommendation is that the annotation of domain concepts in an instructional design helps the retrieval of the desired learning objects according to their corresponding subjects or topics. For example, in the Arapi et al. ID ontology the *LearningObjectType* class is used to specify the characteristics of the desired learning objects to perform a certain learning activity in the instructional design. The domain concepts are specified in this class to enable the computer programme to understand the subject domain of the specified learning object for an instructional design model so that the learning objects could be retrieved at system run-time based on its domain concepts. In addition, the annotation of domain concepts in an instructional design would also help increase the usability of the instructional design, thus allowing for easier searching of instructional designs. As Van Marcke (1998) has pointed out, the instructional design model should be domain-dependent rather than domain-independent, to become usable in any defined learning situation.

However, there are certainly drawbacks to the inclusion of domain information in an instructional design. This includes the possibility of decreasing the reusability due to the annotation of the subject information in the instructional designs (Mizoguchi & Bourdeau, 2000). Nevertheless, the presence of necessary information such as domain knowledge is crucial to making the instructional design usable, since the usability of the instructional design model is diminished if it is not tied to any specific subject domain. For instance, Kolas and Staupe (2004) and Hernández-Leo, et al. (2006) claim that their instructional design templates help develop instructional design more efficiently. However, if they are not tied to any specific subject domain, it is questionable how usable such templates are, since the instructional designers would not understand when and how they should be used. Based on the above discussion, it is therefore concluded that the relation of ID ontology to domain knowledge is a crucial element for the development of a quality ID ontology.

Integration of Pedagogical Knowledge

Instructional design is defined as the description of the teaching and learning processes that take place in a unit of learning (Koper, 2006), whereas pedagogical knowledge guides and assures the design of these processes (Murray, 1996). In other words, pedagogical knowledge facilitates the creation of instructional designs. There are a number of ways in which pedagogical knowledge for assuring the quality of instruction may be applied. The traditional way of using pedagogical knowledge is by building the knowledge into the procedures of the system, but the knowledge is “fixed” so that the system cannot adapt to different requirements for instructional design. To overcome this limitation, De la Teja, Lundgren-Cayrol, and Paquette (2005) employed the MISA method. The MISA method integrates 17 categories of teaching objects so that different design templates can be initiated as guidance for the creation of instructional designs. The quality of instruction is therefore improved by the availability of choice in design templates for developing an instructional design.

Yet another way of using pedagogical knowledge to create quality instruction is to integrate pedagogical knowledge in an ontology. Of the four ID ontologies examined in this study, however, only one, OMNIBUS ontology, integrates educational theories (learning, instructional and instructional design theories) as representative of pedagogical knowledge. The other three ID ontologies state the possibility of describing any pedagogical model but do not allow the integration of such knowledge. The three ontologies are all based on IMS-LD, which does not provide the support necessary for the authoring of instructional designs (De la Teja, et al., 2005). Therefore, the IMS-LD based ontologies, though capable of describing any pedagogical model, would not be adequate for assuring the quality of instruction since the creation of sound instruction still relies on the course designers' expertise in instruction. For this reason, integration of pedagogical knowledge is regarded as another crucial element for a quality ID ontology.

The use of ontology made possible the expression of pedagogical knowledge in a machine-understable language within an entity so that it could be applied in eLearning systems when designing an instruction for different learning situations or needs. The use of pedagogical knowledge also assures the effectivenss of the instruction. For example, by developing OMNIBUS ontology, Mizoguchi, et al. (2007) demonstrated that educational theories can be used as a kind of pedagogical knowledge, and are 'operational' in eLearning systems. This kind of pedagogical knowledge (that is, educational theories) is explicitly represented and accessable to instructional designers in the eLearning systems. For instance, when instructional designers develop a course using this ontology, they simply need to choose a theory that they want to rely on without having to be aware of all the specifics of that pedagogical theory and its implications for the course design. The integration of pedagogical knowledge in an ID ontology enables even novice teachers to create sound instruction.

Though there are clear benefits to integrating various educational theories in ID ontology, the usability of such an ontology is yet to be tested (Mizoguchi, et al., 2007). Separate ontologies that represent instructional design knowledge for each pedagogical model could also be developed (Koper, 2006), that is, developing modular ontologies that integrate a specific theory or a kind of pedagogical knowledge. It is likely that by doing this greater flexibility in terms of the usage of ontology itself will be possible. Above all, since an ID ontology is used to create sound instructional designs, it is crucial for the ontology to integrate pedagogical knowledge so that it offers an effective framework for guiding course designers to construct a quality instructional design.

The Use of Ontology Axioms

Ontology axioms are considered to be one of the modelling primitives of the common vocabulary for an ontology (Staab & Maedche, 2000). They are important as they infer new knowledge in the eLearning systems and enable computational reasoning (Tankeleviciene, 2008). The IMS-LD ontology investigated in this study, includes a set of axioms (defined using F-Logic[10]) for expressing the semantic constraints among

[10] F-Logic (Frame-Logic) is one of the traditional ontology languages, which can be used to define axioms. Its semantics is First Order (Kifer & Lausen, 1989).

concepts. These axioms in the ontology guide the creation of instructional design to ensure their logical consistency. OMNIBUS ontology also defines axioms (using HOZO[11]). The axioms in the ontology validate the instructional design models based on a variety of educational theories. Since there are clear advantages to defining axioms as demonstrated in these two ID ontologies, the use of ontology axioms is considered one of the crucial elements associated with the quality of an ID ontology.

One reason for defining axioms in an ID ontology is to detect the logical consistency between the instructional concepts. Since it is necessary to ensure that the developed instructional design is consistent with its specified concepts, the formal definition of the axioms in an ontology helps assure the quality of the instructional design. Further, it helps achieve the coherence of an ontology as Gruber (1995) suggested. The use of axioms implies less logical reasoning work is needed in the procedures of the eLearning system, because the concepts validation work in current eLearning systems often takes place in the procedures; however these can lack up-to-date information for validating all the concepts. By specifying axioms in an ID ontology, developed instructional designs can be validated via the semantic constraints (i.e., axioms) that include the up-to-date instructional information.

The definition of axioms in an ID ontology may not be appropriate for all situations, since it may limit the applicability of the ontology. Tankeleviciene (2008) suggested that axioms are not necessary for an ontology when an efficient processing method is needed, because the axioms, whilst helping the validation of the specified concepts, may limit the applicability of the ontology.

Ontologies that include axioms are called heavyweight ontologies, meaning that they have higher expressiveness, more constraint, but they are harder to manage and have narrower applicability than lightweight ontologies (that is, ontologies that include no axioms) (Tankeleviciene, 2008). The limitations of the heavyweight ontology are demonstrated in the OMNIBUS ontology which includes many axioms that are difficult to use in practice. Axioms enable the authoring system to do computational reasoning at a much deeper level than would otherwise be the case if axioms were not available. The downside of the ontology is that it is too monolithic and intractable. A preferred approach is to have a modular ontology, which allows one particular instructional design theory that can be easily pulled out. For example, if the ontological

[11] Hozo is another ontology language which is suggested for building heavyweight ontology. Its native language is XML-based frame language (Kozaki, Sunagawa, Kitamura, & Mizoguchi, 2007).

representation of one particular instructional design theory is needed, then just that part of the ontology can be seamlessly pulled out.

Overall, ontology could be an effective language for modelling instructional design to describe all the necessary instructional concepts. However, if deep reasoning of instructional knowledge is not required, the definition of the complex axioms may not be necessary for an ID ontology since the axioms may limit its applicability.

The Availability of an Authoring Tool

Most ID ontologies investigated in this study have authoring tools. The web authoring tool WebLD was developed by Sanchez, Lama, Amorim, and Negrete (2007) for the modelling, validation and execution of the IMS-LD ontology. The theory-awareness authoring tool SMARTIES developed by Mizoguchi, et al. (2007) guides the users in the creation of the theory-valid instructional models based on the OMNIBUS ontology. Further, a Learning Design Editor in the authoring studio of the LOGOS platform[12] was employed to create instructional models based on the ID ontology from Arapi et al. (Arapi, Moumoutzis, & Mylonakis, 2007). However, there has not been any authoring tool developed for LOCO ontology, though the developers have planned to develop tools by extending some of the present learning design editors such as Reload LD Editor (LOCO-Analyst project, 2009). Since the current ID ontologies were developed with different focuses they are not compatible with authoring tools other than those created specifically for them. The current authoring tools that are available for authoring instructional design such as Reload LD Editor and CooperAuthor, have not been made to interpret the semantic concepts defined in ID ontologies (Sanchez, et al., 2008). However, since an authoring tool is needed for implementing ID ontologies, the availability of an authoring tool based on the ontology is considered a crucial element in a quality ID ontology.

Such authoring tools should provide support for modelling and validating instructional design against the ID ontology. For example, WebLD provides three different modelling strategies as a starting point for the authors to create instructional designs. This is similar to SMARTIES which suggests multiple theory-based guidelines to guide the creation of instructional designs. Both tools also help validate instructional design against the formal axioms defined in the ontology. The WebLD validates

[12] The LOGOS platform is a learning platform that includes all functionalities to create and deliver personalised learning experiences (Arapi, Moumoutzis, Mylonakis, et al., 2007).

instructional designs against the axioms to ensure that the model satisfies the IMS-LD specification, whereas SMARTIES validates instructional designs against the axioms to ensure the model is theory-valid.

The authoring tool should be ‘user-friendly’. To be user-friendly, such a tool should provide: first, a graphical user interface where one can move around the instructional design elements; second, explanation of required information; third, support for the steps in the design of instruction (Vignollet, Ferraris, Martel, & Burgos, 2008).

The authoring tool should also support ontology compliance with learning design standards. It is important that the instructional designs developed can be reused and shared amongst different systems so that different teaching strategies are able to be reused and shared. Standardisation of instructional design is an important property to ensure this (De Vries, Tattersall, & Koper, 2006). Learning design standards such as IMS-LD have been suggested for achieving interoperability between systems. Therefore, the authoring tools should provide support to enable instructional designs to be transferred from their ontological format into some kind of standards compliant model such as IMS-LD.

Categorisation of the Elements

The crucial elements in the framework are grouped into four categories, which are Reusability, Personalisation, Quality assurance, and Applicability (see Figure 2). This section discusses the rationale for this categorisation and describes the four categories formed based on the elements.

Reusability

While instructional design knowledge is considered to be necessary to any eLearning system, it is important to enable this kind of knowledge to be reused and shared between different systems (Knight, et al., 2006). Increasing the reusability of an instructional design model is considered as one of the intended purposes of any ID ontology (Knight, et al., 2005). The first three crucial elements discussed earlier, namely: the concepts hierarchy, the selected ontology language, and compliance with standards make particular contributions to the reusability of instructional designs.

The three elements are all concerned with the reusability of instructional designs. The element ‘the use of concepts hierarchy’ is about the use of abstract class concept for an ID ontology. Abstract classes help organise a set of specific instructional design knowledge to be reused. For example, by using the abstract class, the reference to learning object content information could be separated from the description of a learning activity within an instructional design so that the learning activity and the instructional design itself can be reused in any other appropriate learning situation.

The element ‘the selected ontology language’ is concerned with the selection of an appropriate ontology language for developing an ID ontology that could be easily adopted in any eLearning system. Based on the evidence found in the four ID ontologies, OWL is considered as a potential modelling language for developing ID ontology since it facilitates the reusability of any ontology between different systems.

The element ‘compliance with learning standards’ is also concerned with the reusability of instructional design models in different eLearning systems. The IMS-LD specification, as the de facto learning design standard, assures the design model is widely accepted by the other eLearning systems. Therefore, any ID ontologies that are compliant with the IMS-LD are guaranteed to produce reusable instructional design models.

Overall, all three elements focus on the reusability of instructional designs, thus they were grouped under a category named Reusability.

Personalisation

Learning personalisation is another issue which has gained a lot attention in the last few years in the eLearning community (Devedžić, 2006). There is a need to overcome the one-size-fits-all approach, because each learner is unique, that is to say, they have different background knowledge, learning goals, preferences and pace, thus they require a personalised learning environment that can cater for their unique learning needs so that their learning experience become more effective. The settings for this kind of personalisation are fairly restricted in the traditional learning environment (Mizoguchi & Bourdeau, 2000), whereas it is considered to be very achievable in the eLearning environment. Generally speaking, learning personalisation includes tailoring instruction based on learners’ requirements and delivering the learning contents that suit their individual learning activities (Devedžić, 2006). Learner Model Ontology which has been briefly introduced in Chapter 2, describes learners with respect to learning background, preferences, goals and so on. To achieve true personalisation of instruction, ID ontology needs to interact with the Learner Model Ontology to retrieve the personal information about a particular learner.

In order to be able to produce instructional design models that cater well for each individual learner's needs, the relations to both learning style and domain knowledge are the crucial elements in a quality ID ontology. They are both concerned with the ability to personalise instruction based on the Learner Model Ontology. The element 'relations to learning style' is about relating each instructional design to learning style so that an appropriate instructional design can be selected for learners according to their preferred learning style. The element 'relations to domain knowledge' is about relating each instructional design and their learning activities to the subject domain they belong so the developed instructional design model can be selected according to the domain information specified in the learner's profile. Since both elements are concerned with the personalisation aspect of instruction, they are grouped under the category named Personalisation.

Quality Assurance

A valid instructional design model usually requires inclusion of certain concepts that are necessary for describing any teaching and learning actions. For example, a valid IMS-LD model needs to include the core concepts *Learning Objective, Method, Learning Object, Learning Design, Activity* and *Role* (Koper & Olivier, 2004). In relation to developing pedagogically sound instruction, Mizoguchi and Bourdeau (2000) point out the necessity of integrating educational theories into instructional design models since this would assure the quality (effectiveness) of these. However, the question is how to ensure that an instructional design model is both concept-valid as well as theory-valid. Traditionally (before the development of instructional design models using ontology), software programmers usually had to understand the description of the model, and then write its logic and concept constraints into the programme code. Although validation could be done in this way, the flexibility in terms of applying and updating different instructional design models would be lost if they were not understood by the system but only the programmers themselves, since these instructional design models are usually required to be updated frequently. The current way to detect logical consistency using ontology is by the application of ontology axioms (Lama, et al., 2005; Mizoguchi, et al., 2007). Axioms are used for representing knowledge which has to be accepted without proof (Mizoguchi, 1998) and provide semantic constraints among concepts along with rigorous definition of concepts

(Mizoguchi & Bourdeau, 2000).

It has been noted that both of the two crucial elements discussed in the previous section, that is, 'the use of ontology axioms' and 'integration of pedagogical knowledge, focused on assurance of the quality of developed instructional design models. Thus, a new category was formed, namely Quality assurance. The element 'the use of ontology axioms' is included in this category because it concerns the use of axioms to detect the logical consistency in an instructional design model. For example, the axioms can be used to ensure an instructional design model is IMS-LD compliant by configuring the IMS-LD related concepts. This would ensure the relationships between IMS-LD concepts are appropriately expressed in the developed instructional design model. The element 'integration of pedagogical knowledge' relates to the use of pedagogical knowledge such as educational theories to improve or assure the effectiveness of any instruction. It helps develop pedagogically sound instructional design models as well as their overall quality. Thus, it was also considered as one of the quality assurance elements.

Applicability

It is important to consider whether an ID ontology could be easily applied in any authoring system. The various authoring tools help execute (interpret) an ID ontology for producing valid instructional design models. Depending on the complexity of a particular ID ontology, a specific authoring tool is usually developed for its implementation. It would be advantageous if an ID ontology is *standardised* so that it can be executed in any authoring tool, which implies its wider applicability. Alternatively, an ID ontology should have a fully compatible authoring tool to ensure its successful implementation if it cannot be implemented in the other authoring tools.

The crucial element 'the availability of an authoring tool based on the ontology', is concerned with the application of ID ontologies, thus it is grouped in the category named Applicability.

Expert Feedback on the Framework

The developed framework was sent to two experts for validation to ensure its credibility. The feedback received was incorporated into the final framework presented at the beginning of this chapter. This section reports the changes made as suggested by the two experts.

Firstly, both experts pointed out that the terms used in the framework should be made clearer since “these terms are potentially ambiguous or might have different interpretations in different contexts”. For this reason, they provided suggestions for adjustments to the names of some of the crucial elements used in the framework. Expert 1 [13] suggested renaming the element ‘support of standards’ as ‘compliance with standards’, ‘learning styles’ as ‘relations to learning styles’, and ‘domain concepts’ as ‘relations to domain knowledge’. Expert 2 suggested changing the name of the element ‘authoring tool’ to ‘the availability of an authoring tool (based on the ontology)’. These changes were considered helpful, thus they have been integrated into the framework.

Secondly, the initial framework developed included a category called Usability, with an element named ‘inclusion of context information’. Context information is information about the (past) usage of an instructional design or its potential usage (Pawlowski & Bick, 2006). Expert 2 suggested deleting the usability category as well as the element included – ‘inclusion of context information’. He considered information about context is more relevant and important for personalisation of instructional design, since it indicates in which circumstance a particular instructional design was or was not useful for a particular student. The researcher thus decided to place the element ‘inclusion of context information’ into the personalisation category. However, it was found that this element created duplication with the other elements in the category, ‘relations to learning style’ and ‘relations to domain knowledge’, because context information also includes the information about learning styles and domain knowledge. For this reason, the element ‘inclusion of context information’ was completely removed from the framework.

[13] For ethical reasons, both experts were coded with numbers. The criteria for selecting them were described in chapter 3.

CHAPTER 5 CONCLUSION AND FUTURE WORK

This chapter presents the conclusions drawn from this study, discusses the limitations of the study, and suggests areas of future research.

Conclusion

The aim of this study was to identify the elements considered as crucial for a quality Instructional Design (ID) ontology. Based on consideration of these crucial elements, this study also aimed to formulate a framework for evaluating the quality of ID ontologies by synthesising the identified crucial elements. It was expected that such a framework would provide a guideline for practitioners to develop and evaluate any ID ontology, since the framework describes the crucial elements for an ID ontology as well as the steps suggested for considering these in relation to the development process.

To effectively identify all the crucial elements, the term 'quality' was formally defined in this study by adopting the quality definition from the ISO 9126 of the International Organisation for Standardisation. Based on this definition, an ID ontology of high quality must possess certain characteristics that satisfy its intended purpose or function. Through a review of the literature, four intended purposes of an ID ontology were found to include:

1. the ability to increase the expressiveness of the instructional design and facilitate computational reasoning (Lama, et al., 2005);
2. enabling instructional designs to be more easily searched, shared and reused (Knight, et al., 2005);
3. the ability to support automatic construction of personalized eLearning experience (Van Marcke, 1992);
4. the ability to support the creation of pedagogically sound instructional designs (Mizoguchi & Bourdeau, 2000).

Through an examination of four ID ontologies, this study identified the following eight elements as crucial to helping meet the intended purposes of an ID ontology. They are:

1. The use of concepts hierarchy. This is concerned with the use of abstract classes in an ID ontology. It is evident that the structure of instructional design can be greatly improved by using abstract classes that take advantage of inheritance and subsumption mechanisms, thereby enhancing the

reusability of instructional designs.

2. The selected ontology language. This element concerns the selection of a suitable modelling language for developing an ID ontology. Web Ontology Language (OWL) has been widely used by most ID ontology developers because it is defined as the standard ontology language for the Semantic Web by W3C. Using OWL means the ontology can be more easily applied in different eLearning systems. However, the study found that OWL provides limited support in terms of defining further semantic constraints such as axioms. While the definition of axioms is considered to be necessary in an ID ontology to detect the logical consistency between instructional concepts, the other ontology languages such as the F-Logic may instead be employed to define axioms.
3. Compliance with learning standards. It was noted that most ID ontologies developed to date are compliant with IMS-LD specification in order to be read by any standards-compliant delivery system such as learning management systems. In addition, since IMS-LD specification is capable of describing any pedagogical knowledge model, an ID ontology that is compliant with the IMS-LD should also be able to express any kind of pedagogical knowledge model.
4. Relations to learning styles. Consideration of learning styles was found in those developed ID ontologies which had a particular focus on learning personalisation. However, it has also been claimed that the influence of learning styles on learning outcomes cannot be effectively evaluated, thus consideration of the relations to learning styles in an instructional design may not be necessary.
5. Relations to domain knowledge. It has been suggested that an instructional design should relate to its domain knowledge because this helps in the retrieval of the desired learning objects according to their corresponding subjects or topics, which in turn facilitates learning personalisation. Further, the annotation of domain concepts in an instructional design helps increase its usability by allowing for easier search based on a domain concept. However, the inclusion of domain information in an instructional design may also decrease its reusability.
6. Integration of pedagogical knowledge. Pedagogical knowledge is suggested

in an ID ontology because it assures the creation of an effective instruction. Integrating various educational theories in an ID ontology is one example of the application of pedagogical knowledge, but the usability of such an ontology is yet to be tested. In considering the usability of such an ontology, the idea of developing modular ontologies is also proposed, which means integrating only a specific theory, or a kind of pedagogical knowledge in an ontology to enable it to be more flexibly used.

7. The use of ontology axioms. Ontology axioms are suggested for inclusion in an ID ontology because they help detect the logical consistency between instructional concepts. However, the drawback of defining axioms in an ontology is the possibility of limiting its applicability. Therefore, if a deep reasoning of instructional knowledge is not required, the definition of overly complex axioms may not be necessary.
8. The availability of authoring tools (based on the ontology). A compatible authoring tool is considered to be important for implementing a developed ID ontology. Such authoring tools should be user-friendly and support compliance with learning design standards.

The eight elements were grouped into four categories, which are Reusability, Personalisation, Quality assurance, and Applicability. Reusability concerns the extent to which developed instructional designs may be reused, and includes the elements 1, 2, and 3; personalisation relates to the consideration for personalising learning instruction for each learner, and includes the elements 4 and 5; quality assurance focuses on the assurance of the quality for developed instructional design models, and includes the elements 6 and 7; applicability addresses the extent to which the developed ID ontology can be applied in any authoring system, and includes element 8. In considering quality in relation to the development stages of an ID ontology, the elements included in both of the reusability and personalisation categories are of relevance in the modelling stage, whereas the elements in quality assurance category are important at the validation stage, those under applicability category are relevant to execution stage.

The quality framework described in Chapter 4 was developed based on the crucial elements identified and categories formed. It was validated by two experts after it was developed. The feedback received from the experts mainly related to potential ambiguity in some terms used in the framework as well as the moving of one element to a different category, though this subsequently removed all together.

Limitations

The limitations relevant to the research design have been discussed in Chapter 3. These relate first, to the method of analysis and the problem of gaining a full understanding of the context thus a potential failure of identifying key framework categories. This was mitigated by applying analyst triangulation. Second, the reliance on publicly-available information on ID ontologies could have limited the study. However by downloading each of the ontologies and on-going communication with the developers, this problem was minimised. Third, the potential for researcher bias was identified, so the reproducibility of the synthesis is suggested for future research. Finally, the meta-ethnography approach has only recently been used and some processes may be ill-defined.

Implications and Future Work

This research has presented a framework, based on categories and their crucial elements considered necessary for a quality ID ontology. The research findings could be replicated (and updated with newly-developed ID ontologies). In this way the reliability and validity of the quality framework would be further validated.

This study noted that the current ID ontologies have mostly involved developers of advanced technology groups. The majority of them have not involved educational practitioners. Since the purpose of ID ontology is to solve problems for teachers and course designers, future research projects could include the practitioners. In this way the ID ontology is more likely to prove useful and meets the needs of the educationalists, thus better responding to teaching and learning needs.

The evaluation framework developed in this research for assessing the quality of an ID ontology could be implemented in future ID ontologies.

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