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An Ontology-Based Framework for Bridging Learning Design and Learning Content

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ABSTRACT

The paper describes an ontology-based framework for bridging learning design and learning object content. In present solutions, researchers have proposed conceptual models and developed tools for both of those subjects, but without detailed discussions of how they can be used together. In this paper we advocate the use of ontologies to explicitly specify all learning designs, learning objects, and the relations between them, and show how this use of ontologies can result in more effective (semi-)automatic tools and services that increase the level of reusability. We first define a three-part conceptual model that introduces an intermediate level between learning design and learning objects called the learning object context. We then use ontologies to facilitate the representation of these concepts: LOCO is a new ontology based on IMS-LD, ALOCoM is an existing ontology for learning objects, and LOCO-Cite is a new ontology for the learning object contextual model. We conclude by showing the applicability of the proposed framework in a use case study.

Keywords

Learning design, Learning objects, Ontologies, Reusability, Learning content

Introduction

Specifying reusable chunks of learning content and defining an abstract way of describing designs for different units of learning (e.g. courses, lessons etc.) are two of the most current research issues in the e-learning community. First, we have the research in the field of learning objects. Among many important definitions of learning objects such as (Barrit et al., 1999; Richards, 2002; Wiley, 2002) we refer to a very broad definition (Duval, 2002): A learning object is any entity, digital or non-digital, that can be used, re-used, or referenced during technology-supported learning. This definition was used for defining the IEEE LSTC standard for Learning Object Metadata (LOM). In addition to this vague definition, learning objects suffer from a lack of ability to semantically express relations among different types of objects in the context of use in an educational setting (Koper, 2001). Accordingly, to overcome these issues, we have a second group of efforts referred to as learning design (LD) that can be defined as an application of a pedagogical model for a specific learning objective, target group, and a specific context or knowledge domain (Koper & Olivier, 2004). As a response to these activities there is an initiative to define Learning Design-related recommendations at the IMS (IMS-LD-IM, 2003).

Although both of the aforementioned initiatives are interrelated, some questions still have to be answered, such as: How can we employ just some specific parts of a learning object, rather then the learning object as a whole in a specific learning design?; How can we reuse the same learning design in different contexts with different learning objects?; How we can personalize the content of the same learning object according to learners' models in the same learning design?; and How can we develop more extensive learning object and learning design search and ranking services?

In this paper we advocate the approach that ontologies and Semantic Web technologies can offer a solid solution to these semantic issues (Kaykova et al., 2005), because an ontology gives an explicit definition of the shared conceptualization of a certain domain. In fact, the ontology constrains the set of possible mappings between symbols and their meanings (Stojanović et al., 2001). The benefits stemming from the use of Semantic Web technologies in the e-learning context can be recognized in the following services: discovery of resources; composing new resources compliant to the requirements of a particular learner out of the available resources; and user-resource automatic interaction dynamically adapted to the features of the particular user (Panteleyev et al., 2002).

Following these ideas, this paper proposes an ontology-based approach to integrate learning designs and learning objects. First, we develop a conceptual model that differentiates between learning objects and learning object contexts in order to increase the level of reusability of learning designs. Next, to express this model, we create a Semantic Web ontology called Learning Object Context Ontology (LOCO) based on the IMS Learning Design Information Model (IMS-LD-IM, 2003). We use the ALOCoM ontology, a current EU ProLearn NoE effort to define learning object content structure (Jovanović et al., 2005a). Relying on the conceptual model we defined as well as those two ontologies, we identify and explicitly specify relations between ontology classes. Those mappings are also represented in a separate ontology we call LOCO-Cite. On top of those mappings we discuss possible use cases and benefits of the proposed approach.

A brief overview of learning objects and learning design

This section reflects basic concepts and relevant state of the art efforts of both learning objects and learning design.

Learning objects

The broad definition of "learning object" reflects the two very different communities who have an interest in reusable learning resources. The military-industrial community with its heritage in computer-based learning has a strong interest in well-defined content designed in small interactive chunks to address specific learning objectives. This precision is reflected in the US military's ADL SCORM specification (ADL, 2005). On the other hand, the education community reflects an idiosyncratic potlatch of freely-contributed web-based content demonstrating creativity in the use of multi-media and usually broader learner outcomes focused as much on intellectual development as content. While even these sweeping generalizations may be difficult to apply, they do reflect the complexity facing those developing, using and re-using learning objects. Reuse can occur by either prescription/inclusion of the learning object in a course of study, or by using the learning object as an instructional design template - i.e. studying and re-using the instructional approach with new content. It is in this latter use that learning design can be of particular benefit as the instructional design of an object can be made more explicit so that it may be readily adapted for new instructional situations (Sheth et al., 2005). In an effort to promote the locating and re-use of learning objects much effort has recently gone into the interconnection of the repositories or data-warehouses in which learning objects are stored (Richards & Hatala, 2005). While most search and retrieval is based on content descriptions, an explicit learning design vocabulary may shortly enable searching for objects by pedagogical models or learning intentions (Carey et al., 2002).

Currently, the Learning Design world is pulled between the interests of macro and micro instructional design. With its roots in EML (Koper, 2001), a system designed for the mass production of distance education courses, Learning Design has broad applicability in describing the coordination of learning events. Yet at the same time, many of the examples in the best practice guide detail smaller units of learning such as the Versailles cooperative learning scenario. Clearly as LD use increases and it is applied in different scenarios we will see a fleshing out of good examples in both these areas, hopefully with convergence in the language that we use to describe and classify these examples. This is a role for ontologies. Each ontology provides the vocabulary (or names) for referring to the terms in a subject area, as well as the logical statements that describe what the terms are, how they are related to each other, how they can or cannot be related to each other, as well as rules for combining terms and relations to define extensions to the vocabulary (Hendler, 2001). With ontologies we can formalize our conceptual models and automatically perform semantic operations such as searching, and selecting.

This problem has already been addressed in the LO community by proposing ontologies to formalize LO content models (Verbert et al., 2004; Verbert et al., 2005). Essentially, LO content models, providing more precise definitions of LOs, strive to eliminate the vagueness of the LO concept posed by its official definition (Duval, 2002). A deeper insight into LOs structure, provided by content models, facilitates (semi-)automatic repurposing of LO components. The result of that initiative in an Abstract Learning Object Content Model (ALOCoM) (Verbert et al., 2004), the ALOCoM ontology developed on top of that model (Jovanović et al., 2005a), and a set of tools for transforming from/to current learning object formats such as slide presentations (Verbert et al., 2005). We describe this effort in detail later in the paper. Finalizing this section, note also that there are some types of learning objects that are too complex to be simply represented as a sum of their components (e.g. image files).

Learning Design

In this section we list several approaches to expressing learning design and emphasize their advantages and weakness in order to get a greater picture about the present research in the field of learning design.

Koper and Olivier (2004) define learning design as an application of a pedagogical model for a specific learning objective, target group, and a specific context or knowledge domain. An important part of this definition is that pedagogy is conceptually abstracted from context and content, so that excellent pedagogical models can be shared and reused across instructional contexts and subject domains. An example of this is the Learning Activity Management System (LAMS) "What is greatness?" (Dalziel, 2003). In this example, students participate in a series of group discussion activities to try to define greatness. The same sequence of activities can easily be reused by changing the question to "What is jazz?" The subject domain (historical figures or music history) and the instructional context (grade 7 history or grade 10 music) are of peripheral consequence to the pedagogical information (who will do what activities and assume which roles, in what order, and why). The "What is greatness/What is jazz" example is distinct from the well known EML example, "Learning to listen to jazz" (Hummel et al., 2004), that addresses the issue of personalization of learning content and processes.

Learning designs can be represented graphically or formalized according to an information model. Our limited usability tests have indicated that users prefer a graphical representation to conceptualize the learning design, while software systems require precise formalization. No standard has yet been established for the graphical representation of learning designs; however, there are many possible methods (Richards, 2005). LAMS, although not fully IMS LD compliant, makes use of a UML-based approach (Dalziel, 2003), as does (Tattersall, 2004). The MOTPlus editor (Paquette, 2004) uses knowledge representation theory as a basis for graphic representation of learning designs.

The IMS-LD specification provides an information model and XML binding that facilitates the conceptualization and formalization of a learning design for the purposes of standardized information exchange and integration with software systems (IMS-LD-IM, 2003). IMS-LD supersedes previous specifications such as Educational Modeling Language (EML) (Hummel et al., 2004) and adds more flexibility to represent diverse pedagogical models. IMS-LD Levels A, B, and C are currently implemented in the CopperCore run-time environment (Vogten & Martens, 2003) which is an engine for running IMS LD. The Reload (Reload, 2005) and CopperAuthor (CopperAuthor, 2005) editors are fully compliant with IMS-LD and use the CopperCore engine, while the MOTPlus editor can export XML that is compliant with IMS-LD Level A. The Reload editor also allows the creation of IMS metadata, as well as IMS and SCORM content packaging. CopperAuthor is closely integrated with the CopperCore run-time environment, offering a convenient user interface to publish and validate learning designs during the authoring stage. MOTPlus offers a unique graphical interface for "drawing" learning designs, based on meta-knowledge representation of a different information model from IMS LD (Paquette, 2004).

Although using XML enables the sharing of learning designs among different IMS-LD based tools, it is syntactic interoperability that basically validates the grammatical correctness of shared models (Decker et al., 2000). However, to achieve an additional (semantic) level of interoperability we need another solution. In fact, this problem has been already recognized in the learning design community, and a few authors have already proposed the use of ontologies. (Buzza et al., 2004) report that the lack of a shared vocabulary is a major obstacle in cataloguing and searching for learning designs in a repository. Furthermore, Koper and Olivier (2004) describe how integration and coordinated use of ontologies will be a key area of future development in learning design. The establishment of shared vocabularies will be a key part of the creation and acceptance of a learning design ontology. Finally, the IMS-LD specification should allow for the flexible definition of the relations among learning designs and learning content (i.e. learning objects) in order to enable the reuse of the same learning design with different learning content.

We propose to address these points to strengthen the current IMS-LD specification by developing an ontology that will facilitate the reusability of learning designs and learning objects. The ontology must have a clear conceptual framework that minimizes complexity for developers while maintaining flexibility.

Connecting Learning Designs and Learning Objects

After briefly summarizing basic concepts of both learning objects and learning designs in the previous two sections, we propose a conceptual framework for connecting learning designs and learning objects. We start from the premise that learning design offers tremendous potential for content repurposing. Starting with some educational content in the form of learning objects (including images, text, and animations) and some web-based learning support services (chat, messaging, multiple choice tests), the learning designs can choreograph the order in which the content will be presented, how it will be integrated in learning support services, how it will be sequenced and how it will be assigned to learners in a lesson. Conceptually, this can be pictured as pulling learning objects from a repository and using the learning designs to integrate the LOs into activities that involve learners. The IMS-LD specification provides the capability to reference external learning objects through URI property elements and keep a clear separation between the learning design and the content being referenced.

When learning objects are incorporated into a learning design, there may be many possible learning objects to choose from. A course author will be able to automatically search through learning object repositories for suitable content. Ideally the learning objects will contain metadata that will help the course author to identify the most suitable content for a specific purpose. However, this assumes that the learning object will have a single instructional context for which it can be useful. From the standpoint of learning object reuse, it would be advantageous for a learning object to have many different uses, so that expensive multimedia content elements could be reused in as many different learning objects as possible. A learning object that contains pictures of the Acropolis could be used for both a grade 10 art course and a university-level history course. The ALOCoM ontology for repurposing learning object content was designed to facilitate this type of repurposing (Jovanović et al., 2005a). As shown in Figure 1, fragments of content are packaged into learning objects which are incorporated into activities for learners.

Figure 1 illustrates this process in more detail; a learning design is assigned a Method, which will consist of one or more Plays. A Play will be made up of one or more Acts in sequence. Each Act, with its associated Role-parts, Activities, and Environments will utilize a learning object. The learning object may be either static or dynamic. A static learning object is made up of fixed content that has been tightly integrated at design time, making it difficult or impossible to reuse the learning design with different content. Examples of a static learning object would be an interactive Macromedia Flash tutorial or a MPEG movie. A dynamic learning object is one that is constructed out of loosely-bound content objects and has the flexibility to allow for run-time content-repurposing, such a web page. Many learning objects will fall somewhere between the two extremes, but learning objects that are more dynamic will be more suitable for use in this ontology because they maximize the ability to choose content based on context.

The best way to facilitate the integration of learning objects into a learning design without compromising reusability is to treat contexts for LOs (learning object contexts - LOCs) as distinct entities from the LOs themselves, as shown in Figure 2. The LOs exist independently from any presupposed instructional context, meaning that they can be used in any situation in which a course author finds them useful. Within the extensive domain of different instructional contexts, many different LOCs can be created and associated with LOs in a many-to-many relationship. If a course author decides that a particular LO is useful in a grade 7 biology course, a new context object is created associating that LO with that specific context.

Note also that the purpose of LOCs is not to have another group of objects in learning technologies. In fact, the present learning object practice has already recognized that learning object metadata such as IEEE LOM is not flexible enough to fully support learning objects reusability. For example, the eLera learning system proposed introducing an intermediary metadata level besides learning objects metadata in order to keep track of the quality of the learning objects with information such as reviews, comments, or recommendation for future use (Li et al., 2004). This learning object quality information can by created by those who did not create the learning objects nor even used them. Accordingly, such information is not suitable to be kept as a part of learning object metadata.

From a programming perspective, the best way to facilitate LOC is as a distinct class of object from the LOs themselves. In terms of relation databases, the concept of a LOC closely resembles that of a linking table in a relational database. A linking table (Ramakrishnan & Gehrke, 1998) is used for formalization when two objects are associated in a many-to-many relationship. An implication of this type of relationship is that neither object “owns” the other. This is the kind of metaphor we are aiming for with an LOC: a learning design does not “own” a learning object since the learning object could be reusable in many other situation. If we annotate the learning object with context information such as the prerequisites and competencies applicable to the learning object in a grade 7 biology course, we establish an implied ownership relation. In this case, the learning object can be owned by learning designs that target seventh grade biology or an equivalent. If we instead choose to include the information in the learning design, the learning design will be tied to a particular context, which reduces its reusability. Looking again at Figure 2, we see the domain of instructional contexts. The shaded background represents all of the possible ways a given learning design could be used in practice. The learning objects remain outside this domain, so that they can be used by other learning designs in other contexts. In fact, a new LOC is created by associating that LO with that specific context.

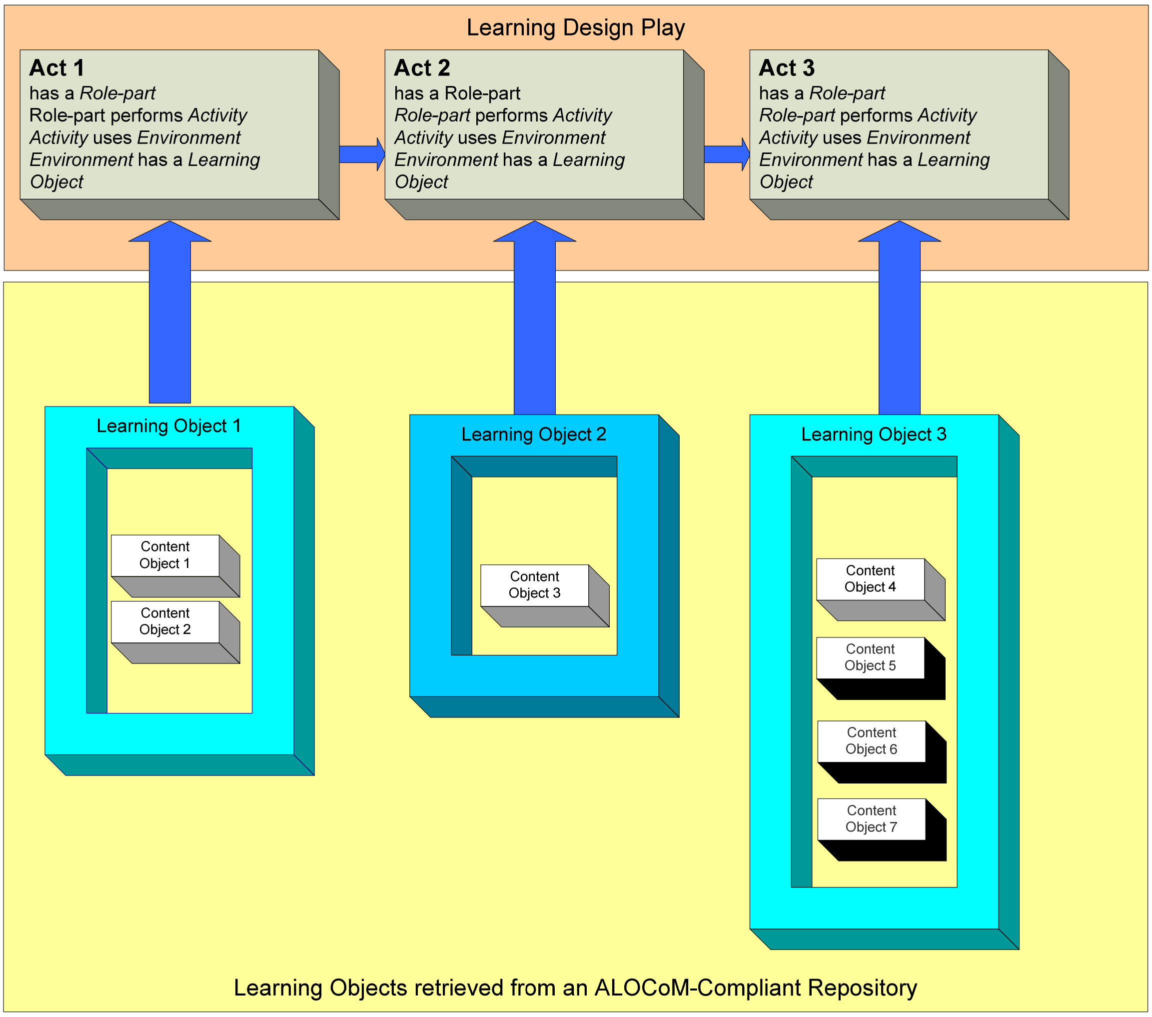

Figure 1. Incorporating digital content into learning designs

Supposing an instructional designer has created a learning design for a grade 7 biology course that includes several activities, each referencing a learning object or service, and defines roles for learners and staff according to the problem-based learning pedagogical model. Included in that learning design is implicit information about what types of learning objects work well when used as activities in a problem-based learning structure, and conversely, that the problem-based learning model is a good model to use these learning objects within. An examination of the learning objectives, prerequisites and roles associated with this activity will help determine similar contexts in which the learning objects can be used.

A learning object context (LOC) would contain data that is specific to a single learning object in a particular instructional context. Learning objectives, competencies, and evaluation would be stored in this object as opposed to the learning object, so that the learning object could be associated with multiple LOCs and different learning objectives, competencies, and evaluation. The LOC could also contain context-specific subject domain ontology information, since the specification of subject domain annotations will be dependent of the context. Table 1 lists the information that should belong to learning design, LOC, and LO according to the proposed model in Figure 2.

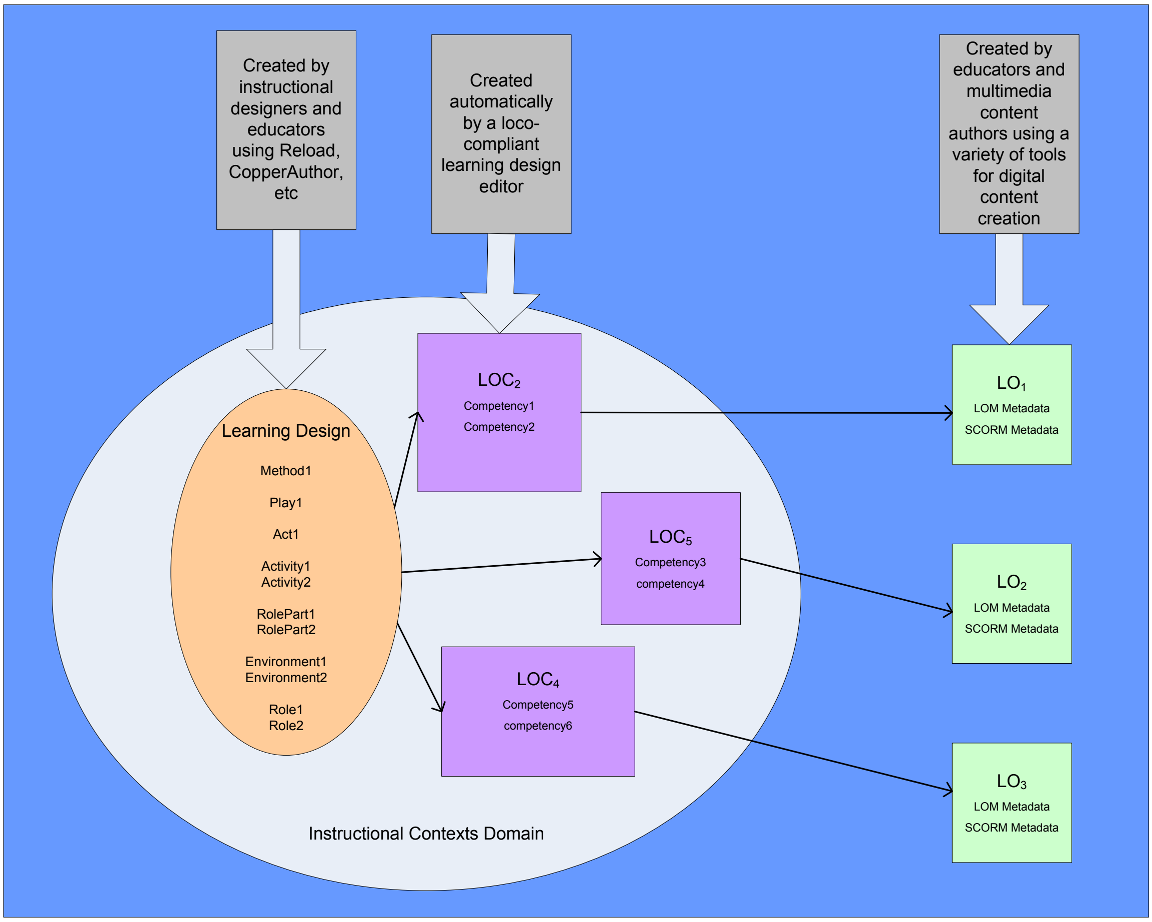

Figure 2. Learning Object Contexts: a conceptual model

*Table 1***.** Information properly associated with a learning design, LOC, and LO

Learning design	Learning object context	Learning object
Created by: Instructional designers and educators	**Created by:** Anyone who reuses a learning design with new learning objects	**Created by:** Educators, multimedia production companies, or software agents through ontology-based content repurposing (ALOCoM)
How created: IMS-LD-compliant learning design editors such as Reload and CopperAuthor	**How created:** Integrated into future tools so as to abstract LOC's from the user and make the process as transparent as possible	**How created:** Virtually any method by which digital content is created
Associated Information: • Lesson Structure – how the activities are sequenced • Roles – how users will interact in single and multi-user learning designs • Pedagogical Models – instructional theory guiding the lesson structure, roles, and method of evaluation • General Learning objectives for chosen methods (not related to context). For example, the learning objectives associated with all problem-based learning.	**Associated Information:** • Content-specific learning objectives and prerequisites • Competencies and specific evaluation of attached competencies • Subject domain annotations particular to a learning situation (e.g. Grade 7 biology terminology) • Quality of experience and suggestions for better use (lessons learned)	**Associated Information:** • LOM and/or SCORM metadata describing the digital resources • Domain specific ontology-based annotation (they can be regarded as a part of LOM as well)

The learning design will be constructed by creating a sequence of activities for learners. Each activity will be associated with a learning object context and a learning object. The learning design will specify roles, sequencing and logistical information, and pedagogical information. The learning design can be reused with different learning objects, and the learning object context will provide clues as to what types of learning objects would be suitable replacements. This will facilitate the adoption of learner modeling techniques and adaptivity (personalization).

The description of a learning design in Table 1 is based on the idea of a generative pattern, a term borrowed from object-oriented software design (Gamma et al., 1995), and is based on the notion that the underlying structure of the design can be abstracted from its implementation, and later be used to instantiate concrete instances of the pattern. This relates closely to the goal of learning design reuse described by (Koper, 2005), to harness the "underlying learning design that is more generic than the practice itself". In the next section we explain how we formalize the proposed conceptual framework using ontologies.

Mapping conceptual model to ontologies

In order to provide an explicit specification (i.e. ontology) of the conceptual model depicted in *Figure 2* we identify the need for the following three ontologies: a) an ontology of learning object content, b) an ontology of learning design, and c) an ontology connecting those ontologies. In the rest of the section we describe each ontology in detail as well as illustrating their usage for representing LDs, LOCs, and LOs.

a) ALOCoM - Ontology of learning object content

Having looked at several content models (e.g. Learnativity, SCORM content aggregation model, CISCO RLO/RIO, NETg), we decided to use the ALOCoM, a recent EU ProLearn NoE effort (Verbert et al., 2004). The ALOCoM was designed to generalize all of these content models, to provide an ontology-based platform for integrating different content models, and to enable (semi-)automatic reuse of components of LOs by explicitly defining their structure (Sheth et al., 2005). In this paper we refer to the ontology built on top of that model (Jovanović et al., 2005a) called the ALOCoM ontology. Actually, we use a revised ALOCoM ontology (Jovanović et al., 2005b) divided into two different parts:

- *ALOCoM Content Structure* ontology enabling a formal representation of LOs decomposed into components;
- *ALOCoM Content Type* ontology defining the educational role of LOs and their components.

Both ontologies are developed in OWL (Bechhofer et al., 2004). The ALOCoM Content Structure ontology distinguishes between content fragments (CFs), content objects (COs) and learning objects (LOs). CFs are content units in their most basic form, like text, audio and video. These elements can be regarded as raw digital resources and cannot be further decomposed. COs aggregate CFs and add navigation. Navigational elements enable sequencing of content fragments in a content object. Besides CFs, COs can also include other COs. LOs aggregate COs around a learning objective. In Figure 3 we show the top-level ontology concepts. Note also that the ontology defines aggregational and navigational relationships between content units.

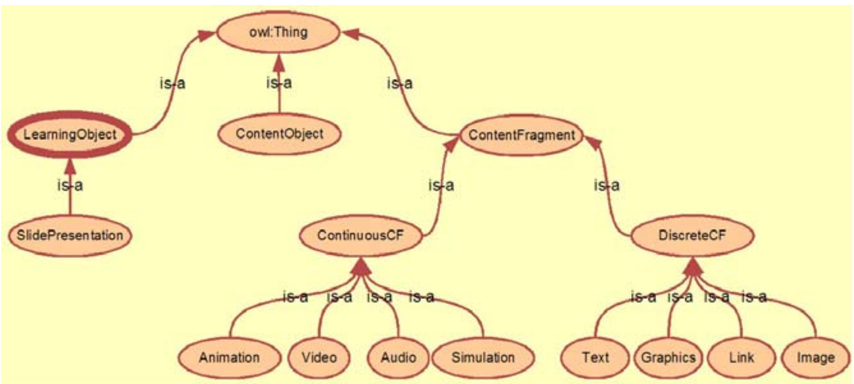

Figure 3. The top level concepts of the ALOCoM Content Structure ontology

The ALOCoM Content Type ontology is also rooted in the Abstract LO Content Model and has CF, CO and LO as the basic, abstract content types. However, these concepts are now regarded from the perspective of educational/instructional roles they might have. Therefore, concepts like Definition, Example, Exercise, Reference are introduced as subclasses of the CO class, whereas concepts such as Tutorial, Lesson, Test are some of the subclasses of the LO class. The development of this ontology was mostly inspired by a thorough examination of existing LO Content Models (Verbert et al., 2004) as well as by a closely related work presented in (Ullrich, 2005).

Note also that both the ALOCoM ontologies are organized as extensible infrastructures that can be further extended with new LO types or content structure elements. Another beneficial point for using ALOCoM is an extensive development of tools able to represent widely accepted formats of LOs (e.g. slide presentation) using ALOCoM ontologies (Verbert et al., 2005).

Having in mind all the aforementioned facts, the ALOCoM ontologies seem to be a very suitable solution that can be combined relatively easily with ontologies describing learning designs based on the IMS-LD specification. Using the capacity of the ALOCoM ontologies to reuse components of LOs, we will be able to reuse learning design with just the components of LOs that are relevant to the new learning design usage scenario. Since we have information about LO components, the same LO can be better personalized according to the learners' specific needs, preferences and styles (e.g. learning using examples rather than formal definitions) when using the same learning design.

b) LOCO - an ontology compatible with IMS-LD

The IMS-LD Information Model and XML binding is the specification for Learning Design (IMS-LD-IM, 2003). As many of the tools and editors for learning design will be developed around this specification it is important to maintain compatibility. The IMS-LD Information Model contains UML diagrams that we used as a blueprint for the creation of an IMS-LD-based ontology named the Learning Object Context Ontology (LOCO). To create the LOCO, we needed to make some changes to the Information Model (IMS-LD-IM, 2003) in order to conform to established good-practice recommendations for ontology design (Noy & McGuinness, 2001), and to resolve some ambiguities and inconsistencies in the information model. We have already reported these inconsistencies in detail in (Knight et al., 2005). To date the LOCO only addresses IMS-LD Level A.

We decided to build the LOCO in the OWL language (Bechhofer et al., 2004) as it is a W3C recommendation for the Semantic Web ontology language. We also used the Protégé OWL plug-in (Knublauch et al., 2004), an OWL ontology editor, to develop the LOCO. Figure 4 shows the LOCO's *is-a* class hierarchy we developed using Protégé. The main emphasis is on the *Learning_object* class since our goal is to make a connection between learning content (e.g. represented in the ALOCoM ontology with the *LearningObject* class) and learning design (i.e. LOCO). In the LOCO, the *Learning_object* class is a subclass of the *ResourceDescription* class. Accordingly, the *Learning_object* class inherits the following properties from the *ResourceDescription* class: *item*, *metadata*, *title*, and *hasResource.*

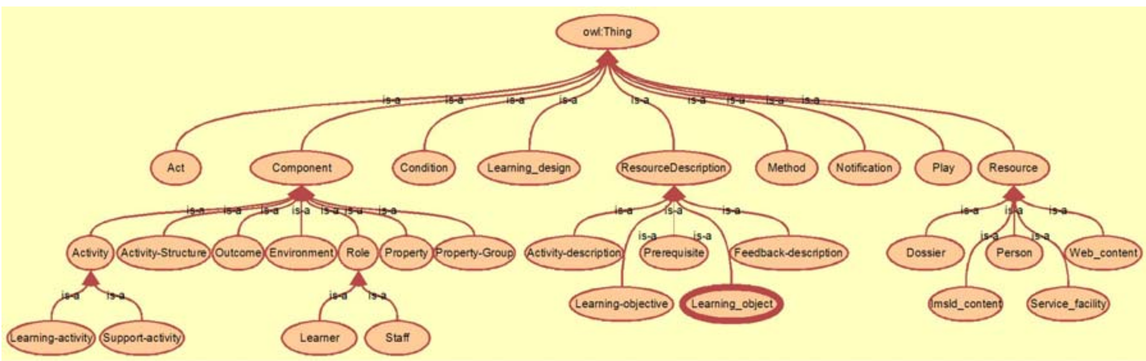

Figure 4. A Protégé screenshot representing a part of class hierarchy of the LOCO

Let us describe the *hasResource* property in order to illustrate one of the class properties in the LOCO. Initially, the range of the *hasResource* property is the *Resource* class. However, according to the IMS-LD specification we additionally have to restrict its range, so that the range is a union of the *web_content* and *Imsld_content* classes (i.e. *hasResource* on the class *Learning_object* can take values that are instance of *web_content* and

Imsld_content classes). This restriction in Protégé OWL plug-in is expressed in a Description Logic (Baader et al., 2002) like form:

$$\forall\ hasResource\ (web\_content \sqcup Imsld\_content)$$

In Figure 5 we give the final definition of the *Learning_object* class expressed in OWL/XML syntax.

```
<owl:Class rdf:ID="Learning_object">
        <rdfs:subClassOf>
                <owl:Restriction>
                        <owl:onProperty>
                                <owl:ObjectProperty rdf:ID="hasResource"/>
                        </owl:onProperty>
                        <owl:allValuesFrom>
                                <owl:Class>
                                        <owl:unionOf rdf:parseType="Collection">
                                                <owl:Class rdf:ID="web_content"/>
                                                <owl:Class rdf:ID="Imsld_content"/>
                                        </owl:unionOf>
                                </owl:Class>
                        </owl:allValuesFrom>
                </owl:Restriction>
        </rdfs:subClassOf>
        <rdfs:subClassOf>
                <owl:Class rdf:ID="ResourceDescription"/>
        </rdfs:subClassOf>
</owl:Class>
```

Figure 5. OWL/XML definition of the Learning_object class in the LOCO

c) LOCO-Cite – an ontology for bridging the learning object content and learning design ontologies

The final step is to create an ontology that serves as a bridge linking the LOCO and ALOCoM ontologies according to the learning object context conceptual model shown in *Figure 2*. Because this makes an explicit reference to a specific learning object, we named the ontology LOCO-Cite. The LOCO and ALOCoM ontologies must be related to each other through the LOCO in an OWL file which links properties and classes across the boundaries of the individual ontologies to create a larger, unified ontology. Since the current versions of Protégé are not designed to work with multiple ontologies in the same view, it is necessary to make the changes to the OWL XML file manually and create a new project in Protégé from this file (Knublauch et al, 2004). The OWL/XML is shown in Figure 6 and indicates how the *LearningObjectContext* class from the LOCO-Cite ontology is linked with the related concepts from both the LOCO (the *Learning_object class* from *Figure 4*) and ALOCoM Content Structure (the *LearningObject* class from *Figure 3*) ontologies. First, we define a relation between the LOCO-Cite ontology and the ALOCoM ontology by saying that the *LearningObjectContext* class from the LOCO-Cite is *equivalentTo* the *LearningObject* class from the ALOCoM ontology. Then, we create a relation between the LOCO-Cite ontology and the LOCO through the *hasLearningObject* property of the LOCO-Cite's *Learning_object* class whose range is the *LearningObject* class from the ALOCoM ontology.

```
<rdf:RDF>
        <owl:Ontology rdf:about="">
                <owl:imports rdf:resource="http://www.lornet.org/LOCO"/>
                <owl:imports rdf:resource="http://www.owl-ontologies.com/alocom-core.owl"/>
        </owl:Ontology>
        <owl:Class rdf:about="http://www.lornet.org/LOCO-Cite#LearningObjectContext">
                <owl:equivalentClass rdf:resource="http://www.lornet.org/LOCO#Learning_object"/>
        </owl:Class>
        <owl:ObjectProperty rdf:about="http://www.lornet.org/LOCO-Cite#hasLearningObject">
                <rdfs:domain rdf:resource="http://www.lornet.org/LOCO-Cite#LearningObjectContext"/>
                <rdfs:range rdf:resource="http://www.owl-ontologies.com/alocom-core.owl#LearningObject"/>
        </owl:ObjectProperty>
</rdf:RDF>
```

Figure 6. A snippet of the OWL/XML document linking LOCO, LOCO-Cite, and ALOCoM ontologies

d) An example of a learning design and learning object content

In this subsection, we illustrate how one can use the ontologies described in the previous three subsections to describe all LO components, LDs, and their relations using LOCs. In fact, we show how one can attach LO components to specific parts of LDs. The main idea is to depict the usage of the "What is greatness" LDs originally created by (Dalziel, 2003) for teaching (and introducing) ontologies. We first describe the LO components we want to use in this example. Figure 7 shows a slide from a slide presentation containing several definitions of ontologies as well as an example of an ontology. The content of the slide can be represented using the ALOCoM ontology. In terms of the ALOCoM ontology, the process of converting currently existing LOs represented in their original formats (e.g. text document, slide presentation) into the ALOCoM ontology-compliant format is called disaggregation. Additionally, the process of disaggregation also includes logical and conceptual organization of LO components by recognizing different content object types defined in the ALOCoM ontology.

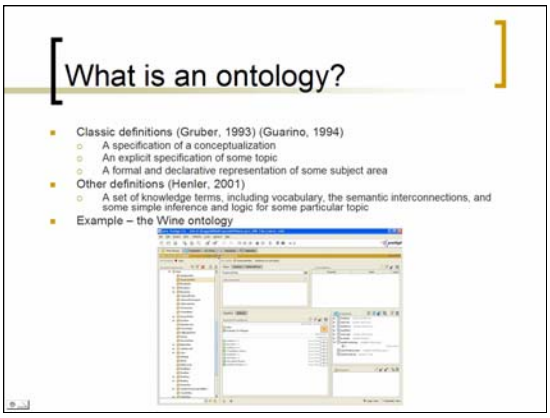

Figure 7. An example of a learning object whose ALOCoM ontology description is shown in Figure 8

Although it was also possible to disaggregate the slide presentation using the ALOCoM toolkit (Verbert et al., 2005), we manually disaggregated the slide for the sake of better readability of the example. Using Protégé, we create content fragments and content objects corresponding to each element in the slide presentation. We then group these pieces into larger content objects using the *hasPart* relation.

Next we anticipate the structure of the LOs we need for construction of our LD. Since we need one LO to serve as an introduction and another LO to serve as an example, we decide to create two ALOCoM LOs, one to hold the introduction content objects and the other to hold the example content objects. Figure 8 shows a representation of the resulting relationships of class instances.

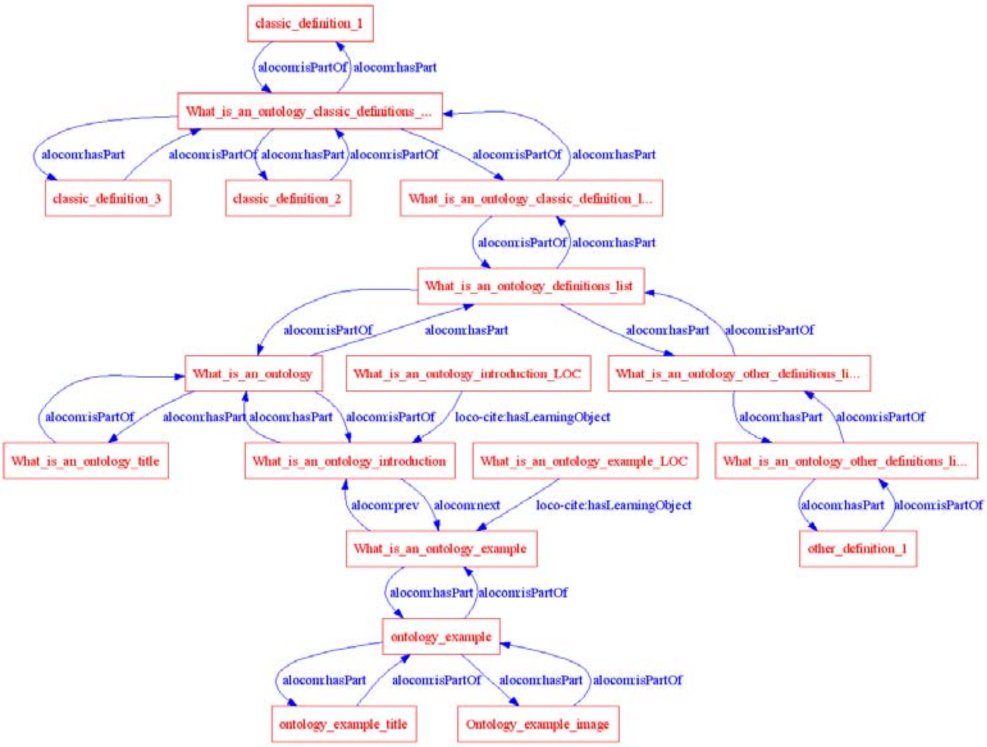

Figure 8. The ALOCoM-based ontology graph of the slide shown in Figure 7

The alocom:LearningObject class instances are named What_is_an_ontology_introduction and What_is_an_ontology_example. Each are associated with alocom:ContentObject or alocom:ContentFragment class instances by the alocom:hasPart and alocom:isPartOf relationships. The LOCs named What_is_an_ontology_introduction_LOC and What_is_an_ontology_example_LOC are instances of the loco-cite:LearningObjectContext class and are used to associate the alocom:LearningObject classes with corresponding loco:LearningObject classes.

We used an existing case study for expressing the "What is greatness" example in IMS-LD (Gorissen, 2004). This learning design provides a set of activities for learners to openly discuss a topic they have just been introduced to, under the supervision of a tutor. We created the learning design in Protégé using the LOCO ontology, and linked the IMS-LD environments to the ALOCoM learning objects by using the loco:hasLearning_object property of the loco:Environment class to associate the environment with the LOC; in this case, the What_is_an_ontology_example_LOC and the What_is_an_ontology_introduction_LOC described in *Figure 8*. The resulting class relationships are shown in Figure 9.

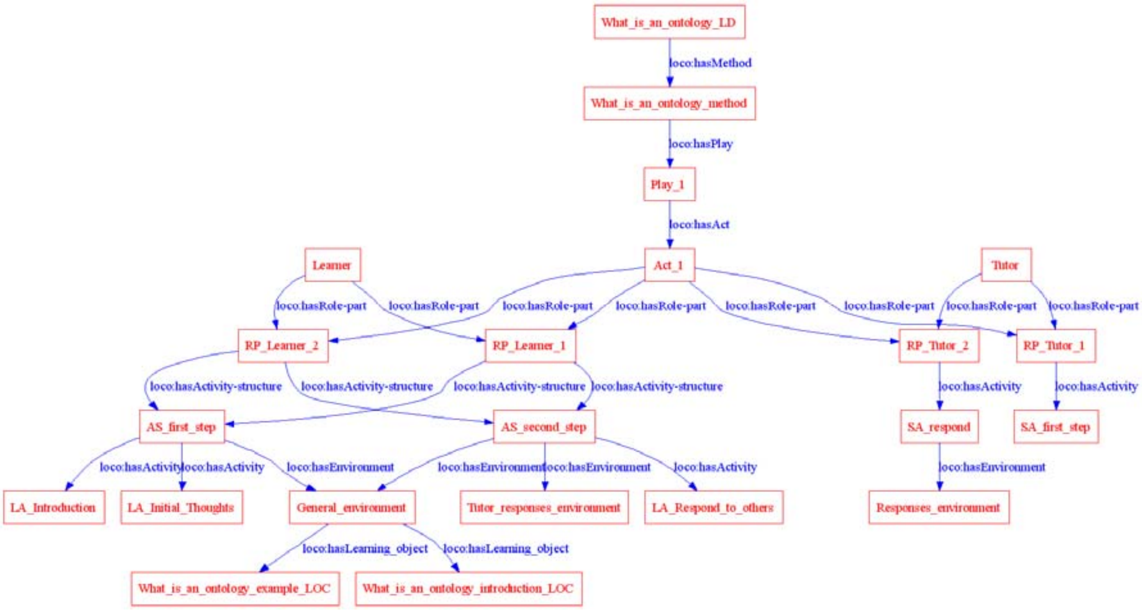

Figure 9. The graph of the LOCO ontology instances representing the "What is greatness?" learning design

Searching for parts of learning designs, searching for learning designs based on the specific content types (e.g. definition) of a specific subject domain, and personalization of the LO content according to learners' profiles within a specific learning design are only a few of the services that we can support by the ontology-based, explicit description of learning designs and LOs as shown in the previous example. In order to clarify one of these ontology-enabled services, we describe competency-based search services in the next section.

Use Cases

LOCO provides an immediate practical benefit in equipping LD with an ontological framework that can be used for the development of Semantic Services. In future, we hope to develop tools (see *Figure 10*) that will leverage the capabilities of ontologies to make it easy to locate and reuse good learning designs, including ones from different subject domain areas. The eventual goals of these tools are to:

- extend some of the present Learning Design Editors (e.g. Reload, LAMS) with the features for exporting/importing LOCO ontology compliant learning designs;
- extend some of the present Learning Design Editors (e.g. Reload, LAMS) with the features for searching LO repositories based on the content ontologies (e.g. ALOCoM) as well as for connecting learning designs to LO content components using LOC defined in LOCO-Cite;
- create LOCO-based repositories of learning designs accessible by present Learning Design Editors.

To illustrate our vision for these tools, we have outlined two use cases that involve searching for learning designs and learning objects based on competencies or quality LOs and LDs for a specific context. The reason for further discussion about competencies is because they have been recently recognized as playing an important role in the selection of learning objects in external or internal repositories and the composition and delivery of the appropriate learning activities (Sicilia, 2005). Having explicitly described competencies using ontologies, one can provide automatic or semi-automatic services for handling competencies in e-learning frameworks. In this paper we distinguish between specific competencies (such as being able to list several definitions of an ontology), and general competencies, which are not tied to a domain and tend to refer to general aptitudes such as group work skills and critical thinking.

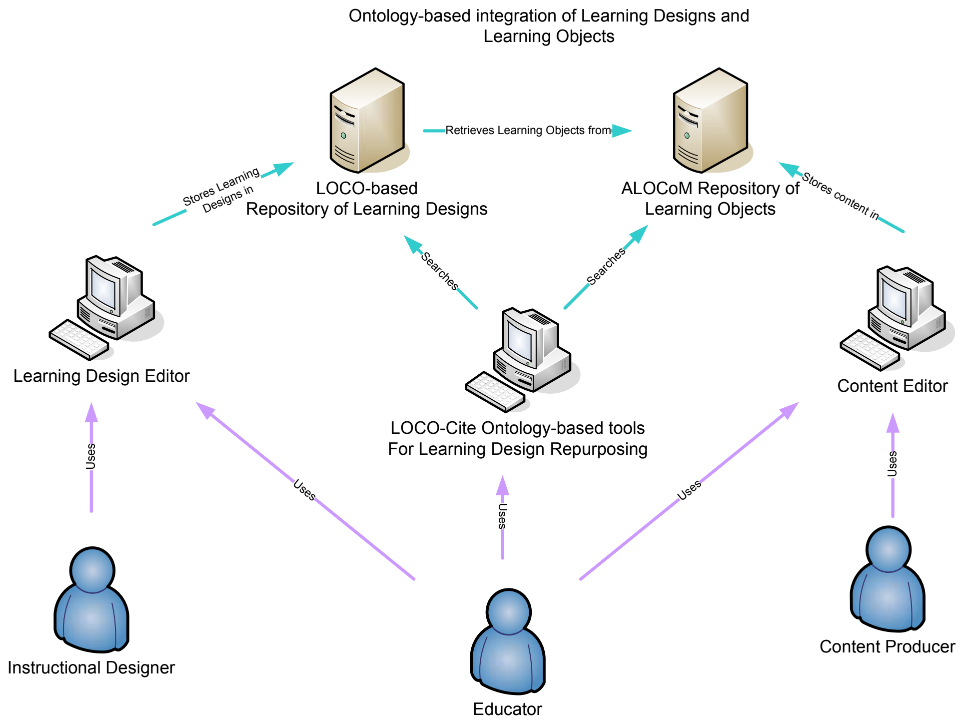

Figure 10. LOCO-based integration of learning designs and learning objects

Here are the two use cases based on the ontology-based conceptual framework for connecting learning designs and learning objects:

Finding a teaching method based on competencies

In this scenario, a teacher will have a list of specific domain competencies and would like to search for the most suitable teaching method in previous practice (if any exist) for these specific domain competencies. Basically, we store the information about the competencies in LOCs that relate LOs from LO repositories (e.g. ALOCoM based) and the learning designs from learning design repositories (e.g. LOCO-based). The rationale for storing the information about the competencies with LOCs rather then with LOs is that the same LO can be used for learning different competencies. By storing the information about the competency with the LOC, we increase the LOs' level of reusability. Using such described LOs, LOCs, and learning designs, the search engine we plan to develop will: take the competencies as the input; look for all LOCs containing these competencies; and return learning designs referred to in the set of found LOCs.

In the case the teacher searches for a learning design that builds on general competencies such as teamwork skills, the above approach for storing competencies with LOCs is applicable as well. Because these skills are not tied to a particular subject domain, the scope of potential learning designs is increased to include learning designs from many different subject areas and levels. The teacher will be able to see learning designs that have worked well building teamwork skills and will substitute learning objects to make the learning design relevant to the specific domain. This would facilitate the reuse of good learning designs across organizational boundaries.

Searching for and selecting quality LOs or learning designs that are most appropriate for a given instructional situation

In this scenario, a teacher performs a search for LOs or LDs as described in scenario 1, but a large number of results are returned. The teacher is given the option to view the results in order of quality ratings, according to

LO and LD reviews associated with the given LOC. Since we have ontology-based descriptions of learning designs and LOs, we can employ ontology-based algorithms for ranking search results by using different weight factors for different ontology relationships (Stojanović et al., 2003). In this case we use the ontology for defining competencies by applying a similar ranking approach for search results. Finally, we can employ different review methods of learning designs like we have with learning objects, such as the eLera system (Li et al., 2004). In that way teachers' quality evaluations can be taken into consideration when ranking learning designs. If we store this information with learning designs, we will decrease their level of reusability. However, by storing them with LOCs, we can employ this information for searching relevant learning designs and still have learning designs in their initial (and hopefully reusable) form.

Conclusions

Having developed an ontology-based framework for connecting learning designs and learning objects consisting of three ontologies (i.e. LOCO, LOCO-Cite, and ALOCoM), we defined a basis for further development of (semi-)automatic services that will be able to reason on top of such an explicit infrastructure. Before we defined that framework, we developed a conceptual model that introduced one additional layer between learning designs and learning objects called learning object contexts. The rationale for having learning object contexts is to relate learning objects and learning designs in a way that increases the level of reusability of both learning objects (e.g. storing the information about learning object competencies with its learning object context, and thus allowing for reusing the same learning object for learning other competencies) and learning designs (e.g. storing the information about quality of a learning design with its learning object contexts). Analyzing the usability of the ontology-based framework, we identified some potential Semantic Services such as:

- Employing the ontology descriptions of learning designs and learning objects to search and reuse them either as a whole or as disaggregated components;
- Finding the most suitable teaching method stored in learning design repositories based on specific competencies;
- Personalizing learning objects according to learners' profiles within a specific learning design by employing an ontology-based description of learning object content;
- Ranking learning designs returned by searches using: different weight factors of ontology relationships defined in the proposed ontologies; users' reviews of both learning designs and learning objects; and ontology-defined competencies.

In the future, we plan to develop tools to extend some of the present learning design editors (e.g. Reload) with support for creating LOCO-based learning designs, with the eventual goal to further evaluate the proposed framework. The proposed LOCO and LOCO-Cite ontologies will serve as the basis for the development of a LOCO-based repository of learning designs and aforementioned ontology-based Semantic Services. The LOCO-Cite ontology will enable, as the result of semantic annotation, the collection of large amounts of data about how learning designs and learning objects are used in practice. From the perspective of learning object content, we plan to set up a learning object repository based on the ALOCoM ontology that will contain learning objects that will be disaggregated using the ALOCoM toolkit (Verbert et al., 2005).

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