

## Ontologies to integrate learning design and learning content

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### Abstract:

The paper presents an ontology based approach to integrate learning designs and learning object content. The main goal is to increase the level of reusability of learning designs by enabling the use of a given learning design with different content. We first define a three-part conceptual model that introduces an intermediary 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 for IMS-LD, ALOCoM is an existing ontology for learning objects, and LOCO-Cite is a new ontology for the contextual model. Building the LOCO ontology required correcting some inconsistencies in the present IMS LD Information Model. Finally, we illustrate the usefulness of the proposed approach on three use cases: finding a teaching method based on domain-related competencies, searching for learning designs based on domain-independent competencies, and creating user recommendations for both learning objects and learning designs.

**Keywords:** Learning design, Learning objects, ontologies, reusability, learning content.

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## 1 Introduction

Specifying reusable chunks of learning content and defining an abstract way for designing different units (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 between different types of objects in the context of the use of 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). This work led to the development of the IMS Learning Design specification (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 only specific parts of a learning object, rather than the learning object as a whole in a specific learning design; and how can we reuse the same learning design in different contexts with different learning objects? A solution is to provide sharable ways for representing both learning object content structure and learning design. Of the currently available technologies, XML rises as a natural solution, but this solution also introduces the same problem that metadata standards already have - lack of formal semantics (Stojanović et al., 2001). The lack of formal semantics inherent in XML is a problem for software developers aiming to achieve semantic interoperability and machine-readability of information (Decker et al., 2000), which is an important aspect of our goal of achieving reusability of learning designs and learning content.

Ontologies and Semantic Web technologies provide a solid solution to this semantics problem, as 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; user-resource automatic interaction dynamically adapted to the features of the particular user (Panteleyev, Puzankov, Sazykin & Sergeev, 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 context 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, 2005). Relying on the conceptual model we have defined as well as these two ontologies, we identify and explicitly specify relations between ontology classes. These mappings are also represented in a separate ontology we call LOCO-Cite. On top of these mappings we discuss possible use cases and benefits of the proposed approach.

## 2 Learning Design: A brief overview

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

Koper and Olivier (Koper & 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. A well-known example of this is the Learning Activity Management System (LAMS) "What is greatness?" example (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).

Learning designs can be represented graphically or formalized according to an information model. No standard has yet been established for the graphical representation of learning designs; however, there are many possible methods (Richards 2005). LAMS 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 facilitate 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 (<http://coppercore.org>). The MOTPlus editor is compatible with the IMS-LD

by exporting an XML format compliant with the IMS-LD XML binding.

Learning Design in its current state of development has a number of areas for improvement that we address in an effort to facilitate reusability:

1. *The lack of an ontology.* The lack of a shared vocabulary is a major obstacle in cataloguing and searching for learning designs in a repository (Buzza et al., 2004). Koper and Olivier (Koper & 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.
2. *Lack of immediate benefit for developers, instructional designers, and educators.* Considering the complexity and difficulty of adapting IMS-LD for a particular use, it must offer advantages. As more IMS-LD compatible run-time environments and authoring tools become available, and as the problems with creating a repository of IMS-LD designs are overcome, it will increasingly make sense to reuse learning designs. The availability of tools to facilitate the reuse of learning designs and learning content would provide effort and cost savings for developers, instructional designers, and educators, and would provide a strong incentive to follow the IMS-LD specification.

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.

### **3 Learning Designs for Content Repurposing**

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 will be many possible learning objects to choose from, provided a repository is available. A course author will be able to search through learning object repositories for suitable content. Ideally the learning objects will contain metadata that will help the course author 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 the 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, 2005). 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. A Flash tutorial would be considered less dynamic than a web page because it is more difficult to extract particular content elements and reuse them. 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.

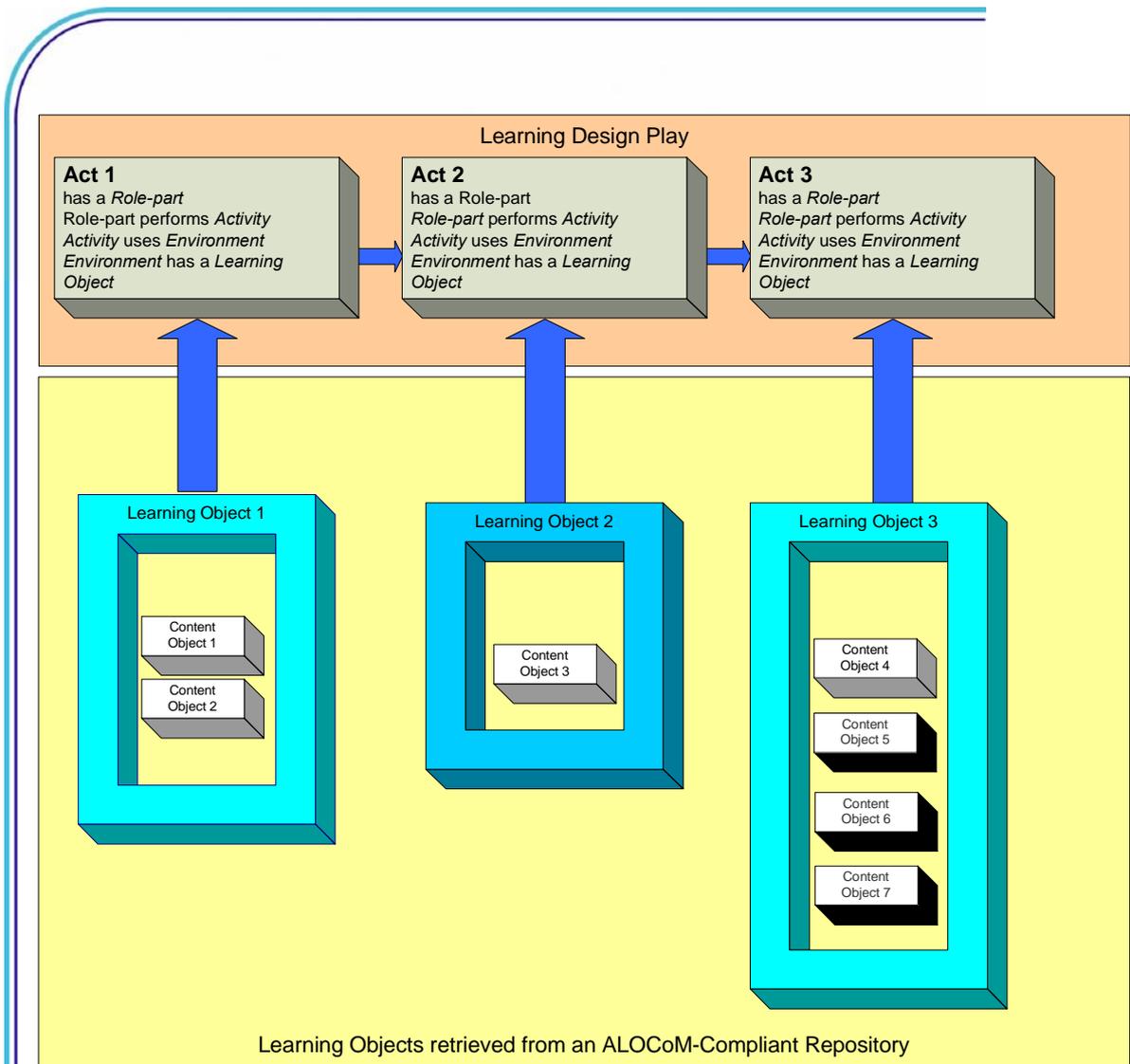


Figure 1: Incorporating digital content into learning designs

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 objects 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 a course author might find 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. The use of a LOC object to facilitate content reuse has advantages over a "template and slot" approach, where template learning designs are made available and each contains various slots that can be populated by appropriate learning objects. Firstly, our goal is that learning designs should include semantic annotations that make it possible for others to retrieve them from repositories without the original author having to take the steps of explicitly creating a template and publishing it. As learning designs are used and improved, that information should be made available without requiring the author to modify the original template. Secondly, the template and slots approach makes it more difficult to locate the many different learning objects that were utilized in a given learning design, since the learning design template may have been copied many times and saved in different locations. LOCs offer the potential to easily access this information and use it to recommend suitable learning objects and learning designs.

From a software engineering perspective, 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 situations. 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. This blue "sea" represents all 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. The LOCs become the links between environments in the learning design that require learning objects, and the learning objects themselves.

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 within which to use these learning objects. 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.

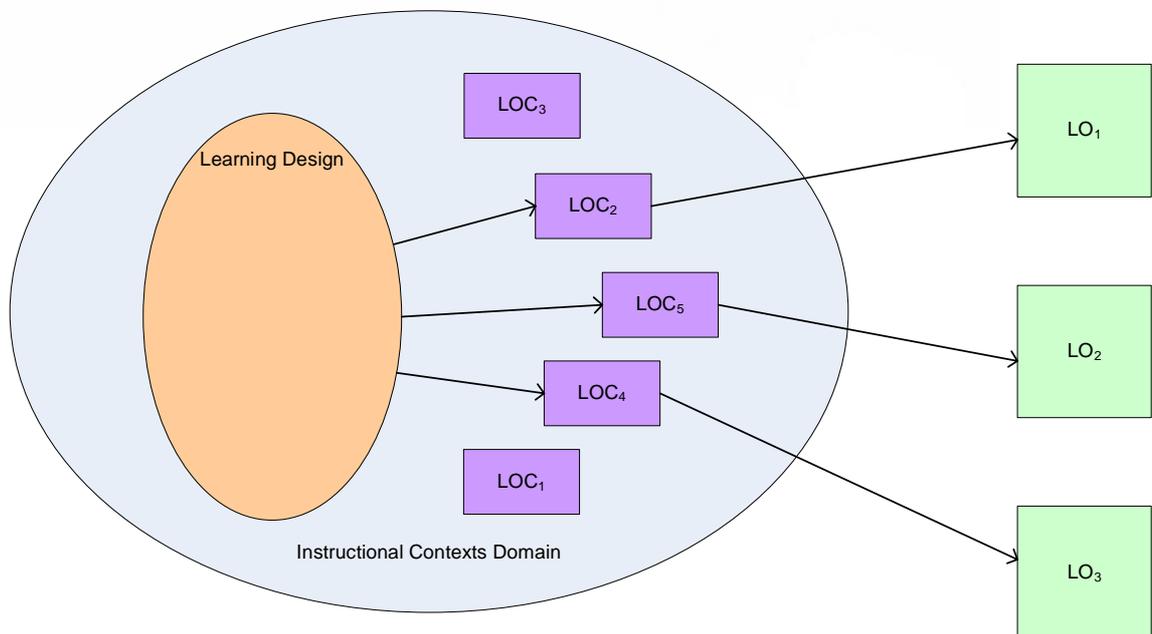


Figure 2: Learning Object Contexts: a conceptual model

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 evaluations would be stored in this object as opposed to with the learning object so that the learning object can be associated with multiple LOCs and different learning objectives, competencies, and evaluations. The LOC could also contain context-specific subject domain ontology information since the specificity of subject domain annotations will be dependent on the context. Table 1 lists the information that should belong to learning design, LOC, and LO according to the proposed model in Figure 2.

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.

Finalizing the section about the proposed approach, note that several questions need to be asked about its suitability:

- How useful will a learning design be without any context, particularly without any specific learning objectives or prerequisites?
- How can existing learning objects that are designed with a specific content, context, and pedagogy be incorporated into this conceptual framework?
- How can learning object reviews and learning design reviews use this LOC information to give best use guidance for the learning objects and learning designs?

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

Learning design	Learning object context	Learning object
<b>Created by:</b> Instructional designers and educators	<b>Created by:</b> Anyone who reuses a learning design with new learning objects	<b>Created by:</b> Educators, multimedia production companies, or software agents through ontology-based content repurposing (ALOCoM)
<b>How created:</b> Learning design editors such as MOTPlus or LAMS	<b>How created:</b> Integrated into future tools so as to abstract LOCs from the user and make the process as transparent as possible	<b>How created:</b> Virtually any method by which digital content is created

<p><b>Associated Information:</b></p> <ul style="list-style-type: none"> <li>• Lesson Structure - how the activities are sequenced</li> <li>• Roles - how users will interact in single and multi-user learning designs</li> <li>• Pedagogical Models - instructional theory guiding the lesson structure, roles, and method of evaluation</li> <li>• General Learning objectives for chosen methods (not related to context). For example, the learning objectives associated with all problem-based learning.</li> </ul>	<p><b>Associated Information:</b></p> <ul style="list-style-type: none"> <li>• Content-specific learning objectives and prerequisites</li> <li>• Competencies and specific evaluation of attached competencies</li> <li>• Subject domain annotations particular to a learning situation (e.g. Grade 7 biology terminology)</li> <li>• Quality of experience and suggestions for better use (lessons learned)</li> </ul>	<p><b>Associated Information:</b></p> <ul style="list-style-type: none"> <li>• LOM and/or SCORM metadata describing the digital resources</li> <li>• Domain specific ontology-based annotation (they can be regarded as a part of LOM as well)</li> </ul>
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To illustrate these relationships we present a concrete example of a learning design used in context. The "What is Greatness" example described earlier in this paper illustrates this point (Dalziel, 2003); anyone who has read a description of this learning design will understand clearly how it works and how it can be reused in a variety of contexts. To make learning designs understandable without context information, it would be helpful to develop a shared vocabulary to describe the pattern characteristic of a learning design without referring to context-specific examples. This need is closely related to the need raised by (Buzza et al., 2004) for a shared vocabulary that can be used to classify learning designs. This vocabulary would include well-established terms from the education community that refer to pedagogical models or best practices, for example, terms such as "collaborative" and "problem-based" learning. If such a shared vocabulary to describe learning design pedagogy were to exist, the general learning objectives and prerequisites associated with the pedagogy would provide context-free information about the learning design. Concrete examples could then be used to supplement understanding.

Our approach is relevant to the development phase of instructional design described in chapter 8 of Koper & Tattersall's (2005) book on Learning Design. This is the stage in which content is added to a learning design. In the existing process, the roles, activities, and environment elements may contain item elements, where an item is a reference to a resource as described in the IMS Content Packaging specification (IMS-CP, 2003). The content referred to by the resource may be either packaged with the design or located elsewhere, enabling reusability.

Our approach improves this process in the following ways:

1. Enabling bi-directional mapping of learning objects to learning designs. Learning object contexts contain links to both the learning design and the learning object.

Being able to determine which learning designs are suitable for a given learning object will allow tools to automatically search repositories of learning object contexts and make recommendations.

2. Linking separate ontologies. To utilize Semantic Web reasoning tools (e.g. OWLJessKB), it is necessary to have an ontology that encapsulates all the learning design and content formalization. Rather than creating a single ontology to cover all these aspects, it is better to use separate ontologies suited to the different aspects: ALOCoM for the content ontology, and LOCO (based on IMS-LD) for the learning design. The third ontology, LOCO-Cite, is created to bridge the other two, based on the conceptual model of the learning object context. Having these three ontologies enables us to use OWLJessKB to apply reasoning according to the use cases we identified, when such reasoning would not be possible if the ontologies were not bridged by the LOCO-Cite ontology.
3. Encouraging the storage of context-related annotations outside of the learning design and the learning content. An example of a context-related annotation is a competency annotation (Ng & Hatala, 2004). When competency annotations are included in the learning object, the learning object can only be reused in the context for which the competency annotations were designed. Alternatively, when competency annotations are packaged with the learning design in the form of content-specific objectives, the learning design is also limited to being used in a specific content area. Another option would be to create duplicate learning designs and learning objects each time a new context is found, removing competency annotations and replacing them with new ones. However, this is a "copy and paste" method that ignores true learning object and learning design reuse and the potential gains realized by creating large interoperable repositories over the internet instead of small, closed repositories on a local computer. From the perspective of reuse, the most suitable place for the competency annotations is in the Learning Object Context.

The LD environment element cannot suffice to encapsulate the functionality of a learning object context. The LD environment refers to the availability of learning objects, communications services, and support services and tools for an activity (IMS-LD-IM, 2003). A learning object context, in addition to describing the availability of learning objects for an activity, also describes the availability of learning designs for a learning object, as well as context-related annotations as described in Table 1.

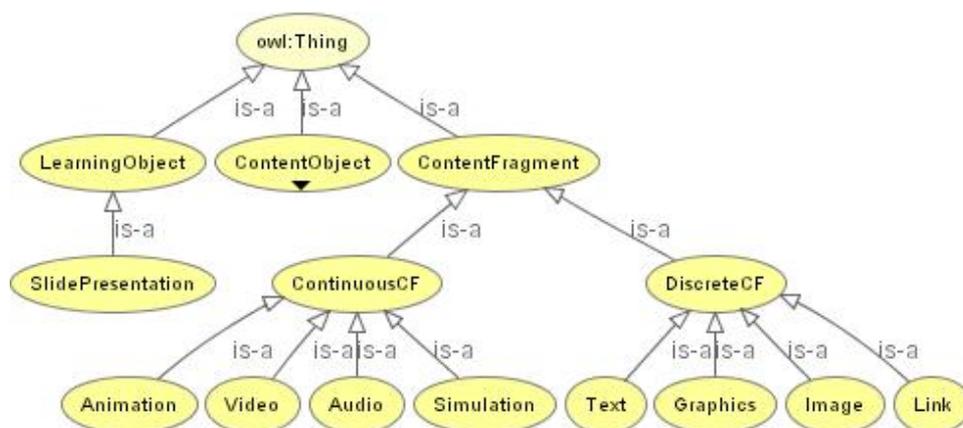
## 4 Mapping conceptual model to ontologies

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.

#### 4.1 ALOCoM - Ontology of learning object content

We decide to use the ALOCoM ontology as an EU ProLearn NoE ontology for representing learning object structure (Verbert et al., 2005). The ontology is based on both the Abstract Learning Object Content Model (Verbert et al., 2004) and IBM's Darwin Information Typing Architecture (DITA) (Priestley, 2001). The ontology is developed in the Web Ontology Language (OWL) (Bechhofer et al., 2004). It defines a number of concepts for depicting different types of content chunks in terms of their granularity (Content Fragment, Content Object and Learning Object), learning/educational role (Definition, Example, Keyword, etc.), and presentation context (Table, Image, Video, etc). In Figure 3 we show a few top-level ontology concepts. The ALOCoM ontology is organized as an extensible infrastructure consisting of: the core part with common concepts for each LO type and an unlimited number of extensions for different LO types (e.g. slides, text documents, etc).



*Figure 3: Top level concepts of the ALOCoM content structure ontology*

#### 4.2 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). Because 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 entitled the Learning Object Context Ontology (LOCO). In order to create the LOCO, we needed to make some changes to the Information Model (IMS-LD-IM, 2003) to conform to established good-practice recommendations for ontology

design (Noy & McGuinness, 2001), and to resolve some ambiguities and inconsistencies in the information model, as described in Table A in Appendix A at the end of the paper. In particular, some object-oriented design principles could be applied to improve the information model. To date the LOCO only addresses IMS-LD Level A.

We also recommend that the design used for the *Property* and *Property-group* classes, as well as the *Activity* and *Activity structure* classes, could be modified to follow the *Composite* design pattern (Gamma et al., 1995). In this pattern, both classes would inherit from an abstract class (see Figure 4). This would provide more proven design, and would be useful when implementing the information model in an object-oriented programming language such as Java. We did not make this change in our ontology for consistency with the IMS-LD Information Model, but recommend it for future revisions of the model.

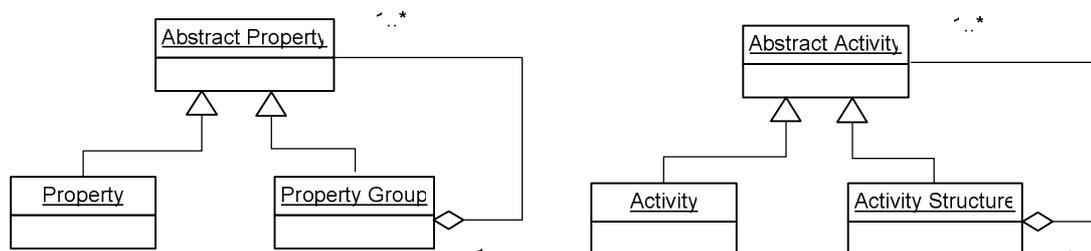


Figure 4: Applying the Composite design pattern to develop the LOCO based on the IMS-LD

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, Ferguson, Noy, & Musen, 2004), an OWL ontology editor, to develop the LOCO. In Figure 5 we show a screenshot of the Protégé editor with a part of the LOCO's class hierarchy. The main emphasis is on the *Learning\_object* class since our goal is to make connections between learning content (e.g. represented in the ALOCoM ontology) and learning design (i.e. LOCO). In the LOCO the *Learning\_object* class is a subclass of the *ResourceDescription* class. The *Learning\_object* class inherits the following properties from the *ResourceDescription* class: *item*, *metadata*, *title*, and *hasResource*.

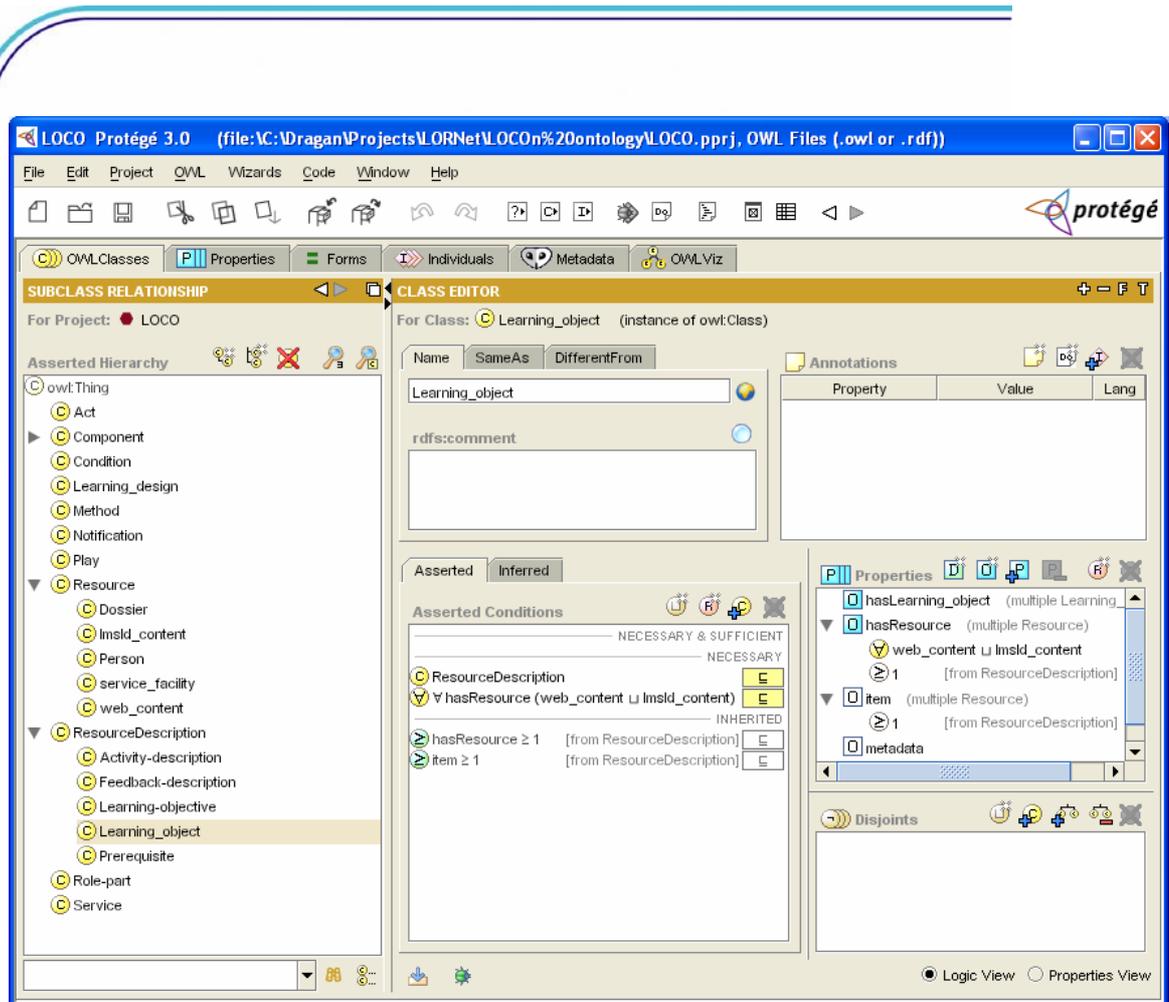


Figure 5: A Protégé screenshot representing a 'part of' class hierarchy of LOCO

Let us describe the *hasResource* property in order to illustrate one example of 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 instances of *web\_content* and *Imsld\_content* classes). This restriction in the Protégé OWL plug-in is expressed in a Description Logic (Baader et al. 2002) like form:

$$\forall \text{hasResource} (\text{web\_content} \sqcup \text{Imsld\_content})$$

In Figure 6 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="ImsId_content"/>
          </owl:unionOf>
        </owl:Class>
      </owl:allValuesFrom>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Class rdf:ID="ResourceDescription"/>
  </rdfs:subClassOf>
</owl:Class>

```

Figure 6: OWL/XML definition of the *Learning\_object* class in the LOCO

### 4.3 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. Since 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 7, indicating how the *LearningObjectContext* class from the LOCO-Cite ontology is linked with the related concepts from both the LOCO and ALOCoM 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 7: OWL file linking LOCO, LOCO-Cite, and ALOCoM ontologies

In Figure 8 we give a screenshot of the Protégé tool containing all three aforementioned ontologies after their integration through the LOCO-Cite ontology. The right two-thirds of the figure also depict the definition of the *LearningObjectContext* class from the LOCO-Cite ontology.

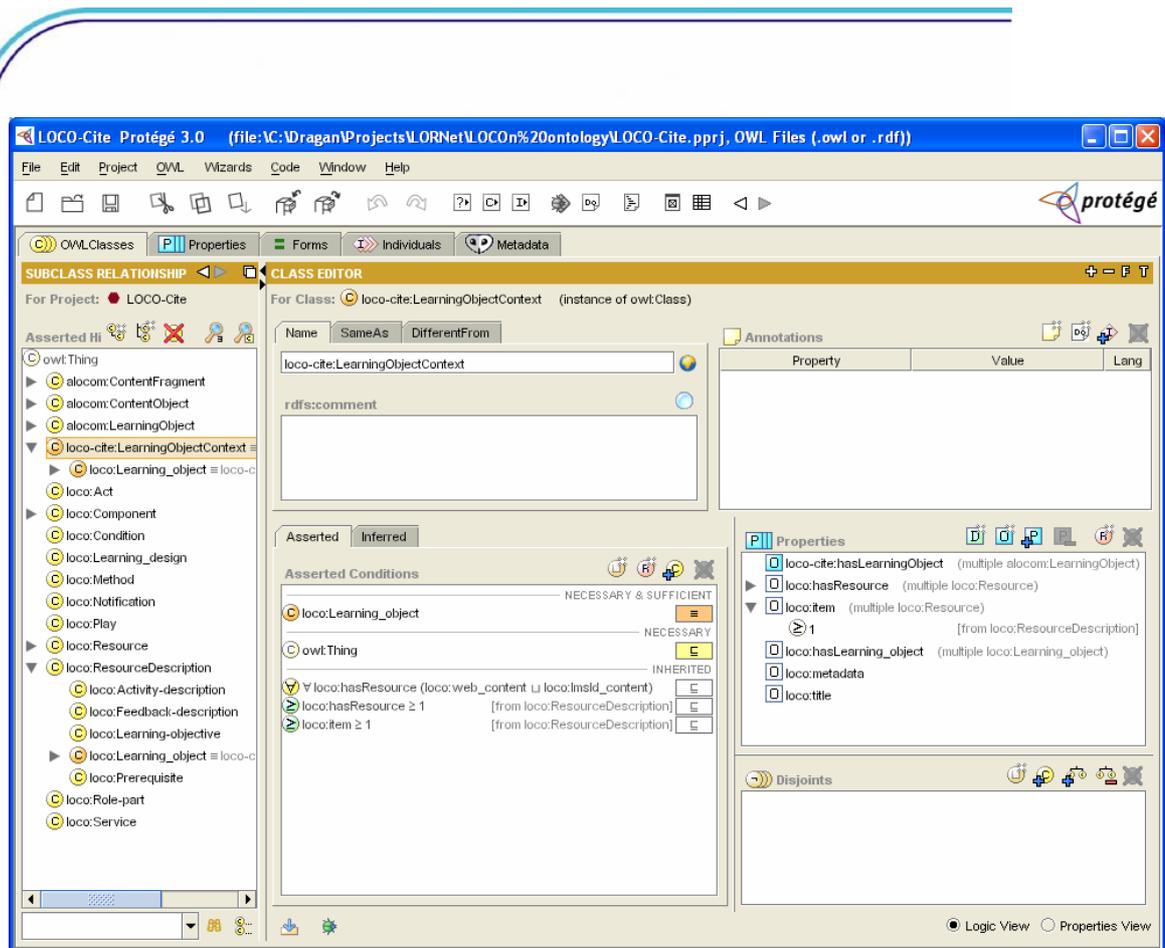


Figure 8: A screenshot of the Protégé editor after connecting the LOCO and the ALOCoM ontology through the LOCO-Cite ontology

## 5 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. These services could harness the formalization of our ontology to facilitate searching for learning objects and learning designs, recommendation, and evaluation. In future, we hope to develop tools (see Figure 9) 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. 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. Essentially, competencies are

formalizations of learning outcomes and are ideal for learning object selection (Ng & Hatala, 2004). We distinguish between specific competencies, which are competencies related to a subject domain 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. We can use two types of competencies as search parameters according to the use cases below:

1. Finding a teaching method based on specific (domain-related) competencies.

In this scenario, a teacher will have a list of specific domain competencies and would like to locate learning objects that have been used to build those specific competencies. After finding the learning objects, the teacher will then be able to search for learning designs that other teachers have used with those learning objects, and have worked in the past to build those specific competencies.

2. Searching for learning designs based on general (domain-independent) competencies.

In this scenario, the teacher will have specific learning objects already selected, and will search for a learning design that builds on general competencies such as teamwork skills. Since 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 scenario would facilitate the reuse of good learning designs across organizational boundaries.

3. Searching for and selecting **quality** LOs or LDs that are most appropriate for a given instructional situation.

In this scenario, a teacher performs a search for LOs or LDs as described in scenarios 1 and 2, but a large number of results are returned. The teacher is given the option to view the results in order of quality, according to LO and LD reviews associated with the given LOC.

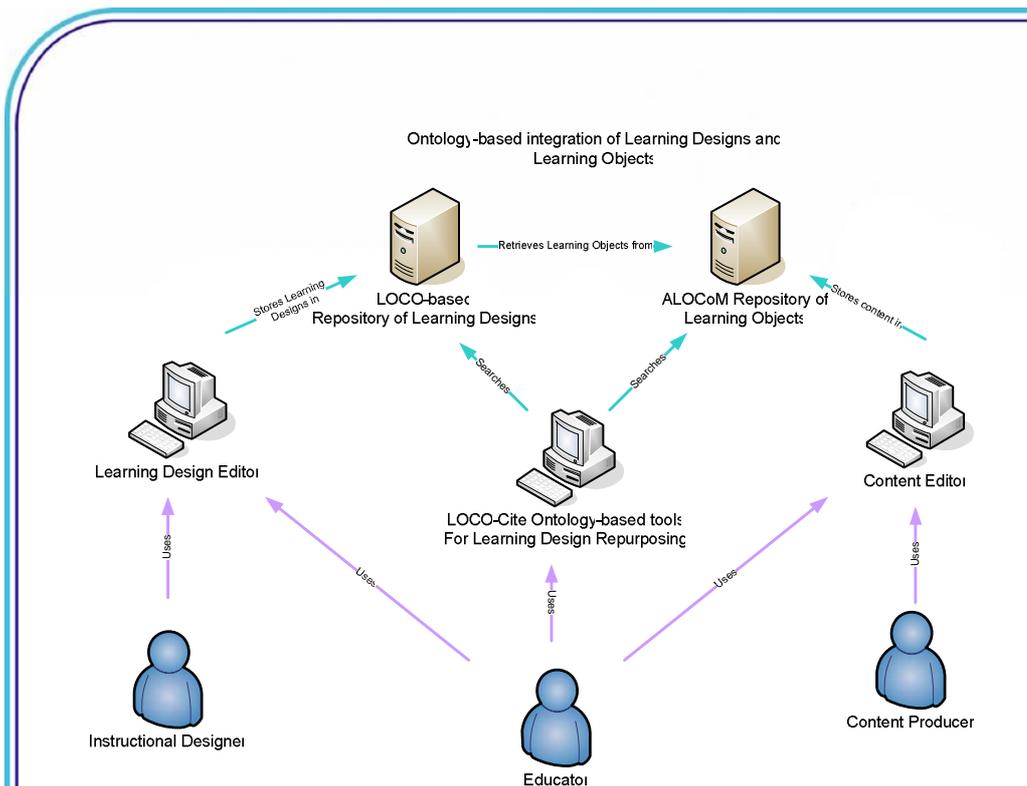


Figure 9: LOCO-based integration of learning designs and learning objects

## 6 Conclusions

In this paper, we proposed a conceptual framework for integrating learning designs and learning objects that promotes reusability. To do this, we introduced the concept of a learning object context as an intermediary between learning designs and learning objects. We then developed three ontologies to implement this framework: the ALOCoM ontology for learning objects, the LOCO ontology for IMS-LD, and the LOCO-Cite ontology for learning object contexts. We explored some of the issues surrounding the creation of an ontology for IMS-LD in OWL using Protégé, and suggested three potential use cases for tools based on these ontologies in order to illustrate possible benefits of our approach.

Since much research has been done recently into the development of ontologies, it is inevitable that ontologies will be developed for learning designs and learning objects. The discussion of how best to structure an ontology to facilitate learning design and learning object reuse is an important aspect of these efforts. The LOCO and LOCO-Cite ontologies we developed implement a conceptual framework that maximizes reusability while maintaining compatibility with current specifications. Also, for educators unfamiliar with

ontologies, we hope this paper will provide insights into why an ontology can be useful and how one goes about creating one.

The proposed LOCO and LOCO-Cite ontologies will serve as the basis for the development a LOCO-based repository of learning designs and LOCO-Cite based search tools and 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. We also hope that our discussion of the LOCO ontology development will promote further discussion and research for the improvement of the IMS-LD specification according to the difficulties we identified.

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## 8 Appendix A

*Table A. Changes to the IMS-LD Information Model*

Item	Description of Change	Example
Class names beginning in lower case	Ontology design best practice recommendations require classes to begin with an upper case letter (Noy & McGuinness, 2001)	The <i>activity</i> class becomes <i>Activity</i>
Class names with two or more words	The class name must be made into a single word by using the underscore ( <i>_</i> ) character	The <i>learning object</i> class becomes <i>Learning_object</i>
Property names the same as class names	Ontology design best practice recommendations suggest properties associated with a class to use the format <i>hasClassname</i> (Noy & McGuinness, 2001)	The <i>play</i> property becomes <i>hasPlay</i> . The <i>Item</i> property becomes <i>hasResource</i>
The relationship between the property and outcome classes (Figure 2.1 of the IMS LD Information Model [ref. to IMS-LD IM specification]) shows the <i>property</i> and <i>outcome</i> classes as being a subclass of <i>component</i> , and also <i>outcome</i> is shown as being a subclass of <i>property</i> .	The <i>outcome</i> class should not be a subclass of the property <i>class</i> , because all common properties in the <i>outcome</i> and <i>property</i> classes are inherited from <i>component</i> .	
The classes that refer to external resources ( <i>activity-description</i> , <i>feedback-description</i> , <i>learning-objective</i> , <i>prerequisite</i> , <i>learning object</i> , and <i>information</i> ) have the same properties and those properties could be inherited from the same superclass to maintain good object oriented design	We created an abstract class called <i>ResourceDescription</i> that provides the common properties of all classes that are used in IMS-LD to refer to external resources	The classes <i>Activity-description</i> , <i>Feedback-description</i> , <i>Learning-objective</i> , <i>Prerequisite</i> , and <i>Learning_object</i> are subclasses of <i>ResourceDescription</i> .

<p>There are some inconsistencies in the way <i>learning objectives</i> and <i>prerequisites</i> are represented in the IMS-LD Information Model Diagrams. In Figure 2.1 of IMS-LD Information model Specification [ref. to IMS-LD IM Spec.], <i>objectives</i> and <i>prerequisites</i> are shown as a single class, while in Figure 2.2, they are shown as separate classes</p>	<p>We created two separate classes, <i>Learning_objective</i> and <i>Prerequisite</i>, however, in classes that have properties for <i>Learning_objectives</i> and <i>Prerequisites</i>, we combined the two properties into a single property, <i>hasLearningObjective-Prerequisite</i> and set the range to the union of <i>Learning_objectives</i> and <i>Prerequisite</i> classes.</p>	<p>The <i>Learning_design</i> class has a single property, <i>hasLearningObjective-Prerequisite</i>, that will refer to both learning objectives and prerequisites.</p>
<p>Use of container classes for sequencing</p>	<p>We removed the container classes from the ontology, since these classes are not necessary at the level of ontology design and are more applicable as implementation details for the XML binding.</p>	<p>The <i>activities</i> and <i>activity</i> classes are replaced with a single <i>Activity</i> class The <i>environments</i> and <i>environment</i> classes are replaced with an <i>Environment</i> class The <i>role</i> and <i>roles</i> classes are replaced with a <i>Role</i> class</p>
<p>Different terms for the same properties shown in Figure 2.2 of the IMS-LD Information Model.</p>	<p>We created equivalent properties to facilitate the use of these properties</p>	<p><i>performs</i> ⇔ <i>hasRole</i> <i>creates</i> ⇔ <i>hasOutcome</i> <i>triggers</i> ⇔ <i>hasNotification</i> <i>using</i> ⇔ <i>hasEnvironment</i></p>
<p>The class <i>Property</i> binds to resource type <i>Dossier</i>, and should bind to the union of resource type <i>Person</i> and <i>Dossier</i> to conform to Figure 2.2 of the IMS-LD Information Model.</p>	<p>Correction in the range on the <i>hasResource</i> property in the <i>Property</i> Class to the union of <i>Dossier</i> and <i>Person</i></p>	