Ontological Representation of Learning Objects: Building Interoperable Vocabulary and Structures

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ABSTRACT

The ontological representation of learning objects is a way to deal with the interoperability and reusability of learning objects (including metadata) through providing a semantic infrastructure that will explicitly declare the semantics and forms of concepts used in labeling learning objects. This paper reports the preliminary result from a learning object ontology construction project, which includes an in-depth study of 14 learning objects and over 500 components in these learning objects. An analysis of the types of components and terms used in these objects reveals that most terms fell into the form and subject categories; few pedagogical terms were used. Drawing findings from literature and case study, the authors use a matrix to show relationships in learning objects and relevant knowledge and technologies. Strategies and methods in ontology development and implementation are also discussed.

Categories and Subject Descriptors: H.3 [**Information Storage and Retrieval**]; E.2 [**Data Storage and Representations**]: Object Representation

General Terms: Documentation, Design**.**

Keywords: Ontologies, Learning Objects, Controlled Vocabulary, Content Structures, Metadata

1. INTRODUCTION

Representation of learning objects involves both content and metadata. Like many other digital objects, learning objects have structures filling with content components, such as learning objectives, procedures, concepts, practice, and assessment. They also need metadata to describe who the creators are, what they are about, and who has what right over them so users can discover, locate, and use these learning objects. Such practice is typically a distributed effort in today's network environment, which results in two contradictory forces in the creation and use of learning objects. On one hand, creators of learning objects do not have a set of controlled vocabulary for labeling the content components and structures. As a result, learning objects come in a wide variety of structures with various labels even for the same type of objects in the same subject area. This makes metadata representation extremely challenging. On the other hand, learning objects need metadata in order to be found and selected by users. Due to the unstructured content and inconsistent naming of content components, automatic metadata generation proved to be difficult, if not impossible, especially for finer metadata representation. So far learning object metadata has been manually created mainly by trained personnel. Although manually created metadata may have better quality, it is very time consuming, expensive, and can hardly keep up with the production of learning objects.

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The issues of vocabulary and structures in learning objects have attracted some attention in recent years. Learning object authoring tools incorporated structured components such as type of learning object, text areas, media components, and so forth [16, 18]. In the metadata community, educational metadata schemes such as IEEE Learning Object Metadata (LOM) and the Gateway to Educational Materials (GEM) metadata set are widely adopted by educational digital library projects. Although the Open Archive Initiative (OAI) provides a venue to attack the interoperability issue for metadata across digital libraries, there are few similar efforts in the learning object design and creation community. While creating sharable, reusable, and interoperable learning objects is actively advocated, not much has been achieved so far.

To make reusable and interoperable learning objects a reality, we will need to add semantic labels to their components, i.e., structured content with proper and consistent semantic labels, so that application programs can, not only read, but also understand the content. The road towards interoperability of learning objects (including metadata) lies in creating a semantic infrastructure that will explicitly declare the semantics and forms of concepts used in labeling learning objects. The semantics includes concept definitions, relationships with other concepts, properties and property types, constraints, and value space. Ontologies as a knowledge modeling tool can help paving the road through its powerful representation capabilities.

2. ONTOLOGICAL MODELING

The benefits of ontological representation of domain knowledge lie in its capabilities of explicitly defining concepts and their attributes and relationships. Coupled with new information technologies, such representation can be encoded in ways that allow for direct conversion into implementation models. This in turn requires ontological modeling of domain knowledge not only to cover the content but also to take into consideration of how the content is to be used and interacted with users. Ontological modeling for learning objects may be divided into three broad areas: content, presentation, and application.

2.1 The Guiding Matrix

The domain of learning objects involves knowledge from learning theory, instructional design, disciplinary knowledge, and enabling technologies (e.g., computer science, linguistics, and information technology). They are related with ontological modeling areas in

[1] The difference between a course packet and a topic packet is that the former is specifically designed for a course while the latter contains materials for a topic and is not necessarily for a course.

different ways. A matrix shown in Table 1 maps their relationships. For example, disciplinary knowledge is what the content of a learning object is about. While content varies in types (e.g., concept, procedure, process, rules, and practice) and levels (e.g., introductory, intermediate, advanced) and presentation comes in text, multimedia, or mixed formats, the application of disciplinary knowledge is focused on actions of reading, playing, listening, and practice. In designing the content, learning objectives, models, and contexts need to be specified and structured with appropriate pedagogy so that learning outcomes can focus on improving learners' competencies in comprehension and other areas. Enabling technologies support content authoring and presentation with ontologies, metadata, and repositories of learning objects. This matrix has an emphasis on the use—disciplinary knowledge vs. application—and learning outcomes—learners' competencies in analysis, comprehension, evaluation, synthesis, and application [5].

Table 3. A matrix of domain knowledge in learning objects

	Content	**Presentation**	**Application**
Disciplinary knowledge	Types, levels	Multimedia, text, mixed	Reading, playing, listening, practice
Learning theory & instructional design	Objectives, learning models, contexts	Structure, naming, relationship, pedagogy	Comprehension, analysis, synthesis, evaluation, application
Enabling technologies	Database, XML, authoring tools	Graphic user interface, tools for annotation & recommendation	Metadata, ontologies, repositories of learning objects

2.2 The Ontology

In modeling the ontology, we used the matrix as a guiding framework to map out what main concept classes should be created, what properties these concept classes have, and how classes may be related. The current version of the learning object ontology has content type, relation, aggregation, production methods, learning objective, media object type, and structure elements. Each class also comes with a set of slots (properties). Several slots have Class or Instance as their slot type. This mechanism allows for classes to be reused or a knowledge schema to be generated for knowledge capturing.

The ontology development took three stages: understanding learning object practice, defining concepts and slots, and capturing pattern instances for the knowledge base.

Understanding learning object practice: Besides studying learning objects in depth, we also informally talked to instructional designers and reviewed literature in learning theory, instructional design, and digital libraries. In building ontologies for educational metadata [14, 15], we analyzed data from a user survey that collected information on the use of the Gateway to Educational Materials (GEM). Among other things, a large number of respondents commented about the need for more specific search options such as topic, idea, and activity as well as more precise search and cross references. Although the survey was primarily aimed at metadata and search, it nevertheless made it clear that the only effective way to meet these user expectations would be to plant semantics in learning object structures that can be recognized and harvested by indexing and metadata programs. As an outcome of this stage's activities and research, the guiding matrix shows the knowledge and technologies involved in the learning object domain.

Defining concepts and slots: Each concept in the ontology contains a number of items to be defined: the name, definition in natural language, constraint, type of concept (abstract or concrete), and slots. Since the type of concept decides whether or not it can have direct instances and what type of slot the concept can have, we made a rule that a concept should be the concrete type if instances need to be captured for the knowledge base; otherwise it should be an abstract concept. A slot is similar to a field in a database table—it has a name, type, cardinality, and facets (value space or referenced classes). Proper use of slot types *Class* and *Instance* can give ontologies great leverage to reusing classes and building associations. Relations, Learning-unit, and Learning objectives are three classes in the ontology that use either class or instance as the slot type.

Capturing pattern instances: One of the benefits for having an ontology is that the concept classes and properties can be used as a framework to perform knowledge acquisition for the knowledge base. This is done through converting the classes and slots into either a database schema or XML schema/Resource Description Framework (RDF) schema, whereas instances may be converted into data in XML or database format. The learning object ontology is still under development and its complete content may be found at http://web.syr.edu/~jqin/LO/LOV/. Other related ontologies include the IEEE LOM (http://web.syr.edu/~jqin/LO/LOM_html/index.html) and EduOnto (http://web.syr.edu/~jqin/eduonto/). Both are converted and modified based on the respective metadata standards.

3. CONCLUSIONS

In this paper we discussed a guiding framework for and process of constructing a learning object ontology, which connects different areas of knowledge and technologies to the content, presentation, and application of learning objects. The ontology we built is still being developed in order to fully represent the knowledge and technologies in the learning object domain. The main contribution of our work is adding a semantic layer that has been missing from standards, metadata, pedagogy, and tool development in the learning object domain. In the effort to develop Semantic Web, we believe that learning object ontology has an important role in implementing standards for effective delivery of content and enriching pedagogical models of learning.

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