An Educational Ontology based on Metadata Standards

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Abstract. In this paper, we present EUME Onto, an educational ontology that describes terms of learning design, contents and resources. This ontology is intended to (1) organize the available information; and (2) provide the grounds of the knowledge based for an Intelligent Learning Management System. EUME Onto is based on metadata standards such as IMS-EML, LOM 1484, OASIS DocBook and FIPA Ontology Devices. To reduce implementation efforts, the WebODE platform, a scalable and integrated workbench for ontological engineering, has been used.

Keywords: Ontologies; Learning Metadata; Learning Design

1. Introduction

There exists a growing demand for educational software to support the different teaching/learning methodologies. Several educational systems offering instructional design tools and instructional standards compliance facilities have been developed: Angel 5.5, Bazaar 7, Blackboard 6, CourseWork, FirstClass, WebCT (Edutools, 2003). However, these commercial systems lack of pedagogical flexibility and suffer interoperability problems: they are either pedagogically specific (CSCL supports only, for example), they do not offer specific tools for the learning analysis process or they do not offer metadata compliance at the Learning Design level, for example.

In this paper, we describe EUME Onto, an educational ontology that contains concepts of learning design, learning contents and learning resources. This ontology is intended to (1) organize the available information, and (2) provide the grounds of the knowledge Based of an Intelligent Learning Management System (ILMS). EUME Onto is based on metadata standards such as: IMS EML (IMS project, 2003), LOM 1484 (LTSC, 2003), OASIS DocBook (DocBook, 2003) and FIPA Ontology Devices (FIPA, 2003). In order to reduce implementation efforts, the WebODE platform (WebODE, 2003), a scalable and integrated workbench for ontological engineering, has been used.

This work emerged in the context of the EUME project – Ubiquitous and Multimedia Environment for Education (http://www.eume.net) – which aims to develop an ILMS intended to support traditional learning as well as other emerging methodologies, like collaborative learning. At this moment, the EUME environment is constituted by mobile devices (PDAs), a video projector, a simple interactive electronic whiteboard, a PC (classroom server). The current prototype provides different resource management services like the remote control of a video projector, the remote management of stored files (.ppt, .doc, .htm), web page surfing, and record/access of teacher annotations in the whiteboard.

The paper is organized as follows: (1) an Introduction with a motivation of this work (2) a brief overview of Learning Metadata Standardization efforts, (3) a somewhat Learning Design concept and IMS Learning Design specification overview, (4) the rundown of EUME Onto educational ontology, (5) a discussion about this work; and (5) the Future Works planned.
2. Learning Metadata and Standardization efforts

Metadata standards aim to provide interoperability, modularization and reuse of components in a software system. Several international organizations have contributed to the development of educational metadata standards: LTSC/IEEE (LTSC 2003); IMS Global Learning Consortium (IMS project 2003); CEN – European Committee for Standardization (CEN 2003); DCMI – Dublin Core Metadata Initiative (Dublin Core 2003); ARIADNE – the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE 2003); and ADL – Advanced Distributed Learning Initiative (ADL 2003).

These organisms are working towards (1) architecture and terms glossary definitions; (2) concepts related to students and/or learning contents – localization, semantic descriptions and protocols of information interchange of instructional objects; and (3) identification and management of information and meta-information. The results may be classified in two levels (Anido-Rifón et al. 2002):

a) *Information model specification* about format, syntax and semantic of data to be transferred between heterogeneous platforms. In this category we could include metadata specifications such as IEEE 1484 Learning Object Metadata, Dublin Core, SCORM or IMS EML.

b) *Architectures, software components and interfaces specification* in which we can include the IEEE LTSC LTSA, Learning Technology Systems Architecture, that define a conceptual model which can be applicable to several learning scenarios.

In the EUME system, we have decided to use LOM and IMS EML as the metadata standards from which the learning objects and entities of our software system will be modelled. These learning standards are oriented to the definition of digital contents, and specification of the syntax of the educational objects. IMS focuses on a minimal properties set that facilitates search, evaluation, acquisition and reuse of educational objects (Anido-Rifón 2002); whereas IMS EML (Educational Modelling Language) is a specification of an ordered series of activities. This activities are carried out by the learners (students) and the staff (teachers) in an environment context, which consists of learning objects and services (IMS project, 2003). Furthermore, a common model reside behind all distinct learning/teaching theory: conducist, cognitivist, social constructivism and eclectic model (Koper 2001). Therefore, EML is a language to modelling educational objects.

Moreover, the IMS Learning Design specification deals with dynamic aspects of the learning design, integrating a learning method and the resources needed at the learning process, regarding whichever pedagogical approach. IMS uses the Learning Design concept as a description of a method enabling learners to attain certain learning objectives by performing certain activities in a certain order in the context of a certain environment. IMS provides a conceptual vocabulary of Learning Design according with the UML diagram shown in the Figure 1 (IMS 2003).

3. The EUME Onto Educational Ontology

In this work we describe an educational ontology, called *EUME Onto*, based on metadata specifications such as EML, LOM and DocBook. and meets the completeness, pedagogical flexibility, personalization, formalization, reproducibility, interoperability, compatibility and reusability (Koper 2001). The study of these specifications has lead to the discovery of implicit relations (such taxonomic relations) between the metadata terms, and also the addition of axioms, which add a more precise definition of the concepts.
The EUME Onto is composed by a set of related ontologies: (1) Learning Design, which is based on IMS specification (IMS project, 2003); (2) Learning Contents, and Educational/Didactical Ontologies, which is based on OASIS DocBook (DocBook, 2003) and describes the learning objects referred in the learning design (such as Books, Chapters, Web Pages, etc); and (3) Hardware Resource, which is based on FIPA Ontology Devices (FIPA, 2003).

3.1 EUME Onto: Learning Design

The aim of the Learning Design Ontology is to capture the knowledge needed by the teacher to carry out the planning of the learning objectives and to specify the learning activities, pre-requisites, methods and resource/contents that will be used in a course. This ontology is based on the IMS specification (IMS 2003), which roots on the Educational Modeling Language (EML) (EML 2003) and incorporates all concepts contained in the conceptual model of the IMS specification level A. Furthermore, we have enhanced this ontology adding new terms obtained during the knowledge acquisition of the EUME project and axioms that define the semantic of the ontology concepts. Although in this paper we are centered in describe the taxonomy of the learning design ontology, we introduce some axioms to show how they can constraint the situations in which the concepts are used. Figure 1 shows an excerpt of the learning design ontology where we distinguish between the IMS specification modeling (in blue) and the new ontology concepts and relationships that we have introduced (in gray).

3.1.1 Learning Objectives, Roles and Resources

The learning design starts with the learning objectives definition that can be specified at several levels of generality. For example, learning objectives can be referred at a course, and they are expressed as general objectives related to a book, or at a lesson, in which the learning objectives are associated with a chapter.

The IMS specification for learning objectives can be basically considered as a textual description. However, in EUME Onto we have associated learning objectives with conditions and criteria. Conditions are related with the circumstances (or context) in which the objective will be achieved. For example, in the objective formulated as the students, at the end of the activity, should be able to translate texts in German without a dictionary, the condition would be without a dictionary. On the other hand, criteria indicate the degree in which the learning objectives should be achieved. Usually, these criteria are expressed with numeric thresholds. For example, in the previous activity, the learning objective would be achieved when the students translates at least the 70% of the proposed texts.

Roles specify the participants of the learning process. According with the IMS specification there are two basic roles: learner and staff, which can be specialized in more specific roles. An instance of one of these roles, however, can play a different role depending on the learning process to be executed. For example, in an educational game learning activity, the players (aka learners) may have changed their roles (director, manager, etc.). The attribute create-new indicates whether multiple occurrences of a role may be created during runtime. Therefore, learner and staff concepts of our ontology can not be an exhaustive partition: both concepts can have the same instances.

On the other hand, activities are carried out in an environment that contains resources used by the roles in the development of a learning activity. These resources are viewed as learning objects that will be described in an ontology following a metadata specification (explained in section 4).
3.1.2 Activities and Activity Structure

An activity is a set of learning acts performed to achieve an objective and the sequence of all the activities will determine the “learning workflow” in a learning design. In the EUME Onto we have considered two different activities: learning activity and support activity. The first one is a set of acts performed by students using learning resources within an environment to achieve the learning objectives. The second one is referred to activities that are not carried out to achieve certain objective, but to support the learning activities. The control of the execution and completion of a learning activity could be performed by an Intelligent Learning Management System (ILMS) using the following attributes: isVisible (can be executed), complete-activity and on-completion-description. The value of the attribute complete-activity indicates when an activity is completed: user-choice, this means that the user, using a system interface, may decide when then activity is completed; and (2) time-limit, meaning that the activity is completed when a certain amount of time has passed.

When we group several activities we are defining an activity structure, which can also group other activity structures. In the specification of an activity structure we use the attributes: number-to-select, which indicates the number of activities that we must be executed to complete the activity structure; sort, which determines whether the activities are activated by the user (typically the learner) or in order according to their visibility; and structure-type indicates whether activity-structure is a sequence or a selection. The activity-

![Figure 1: An excerpt of the EUME Onto educational ontology where bluish concepts denote the original IMS specification and grayish concepts are related with extensions that we have introduced to this specification.](image-url)
structures can be pre-active, active and post-active (see Figure 2) and they represents phases in the learning design. In the pre-active phase we find all the activities performed by the staff when she elaborates the learning design. Examples of these activities are the definitions of the learning objectives/prerequisites, roles, activities, environment, etc. In the active phase we group all the activities performed during the moments that the learning process occurs: they are the class learning activities. In the post-active phase all the activities to be taken after the learning process. For example, feedback activities used to refine the lessons plan. This classification of phases was obtained during the knowledge acquirement meetings with the participation of education experts. For these activities we have identified axioms that constraint its execution order or sequence. For example, it is not permit to execute the active phase before the post-active phase.

3.1.3 Learning Design Example

In order to illustrate the EUME Onto ontology an example of activity is provided. The conceptualization of this example is shown in Figure 2. The example is the following:

Based on previous concepts defined about communication and given a filmed situation in which several forms of communication are portrayed, the students could be asked to describe 10 categories of communication shown in the film in an oral exposition without notes and be able to describe at least 7 categories.

It is important to emphasize that during the activity Introduce Assignments, bibliographical

Figure 2: Example of the instantiation of the ontology of learning design.
references and notes were provided, whereas lessons 6, 7, and 8 were cited as the class where the concepts should be defined. Figure 2 show how the instance class have instances of this example with EUME Onto vocabulary terms:

- **Learning objective**: to verify the student comprehension about communication concepts. Conditions: oral exposition without notes. Criteria: describe at least 7 categories.
- **Prerequisites**: “concepts about communications categories”.
- **Roles**: teacher assigned as staff and student assigned as learner.
- **Activities**: could be considered the Explain Concepts, Demonstrate Examples and Clarify Issues as completed learning activities for the previous communication concepts. These activities are an instance of Staff learning activity class that is a subclass of Learning Activity; The activities Evaluation and Answer Evaluation could be considered as a support activities for the current activity. This activities are both an instance of Staff support activity and Learner support activity class that is a subclass of Support Activity.
- **Environment**: could be considered the film, books, and articles of the bibliographical references, the whiteboard teacher annotations made with the Mimio device (see section 1) and PDAs as the learning objects of this environment.

### 4.2 Learning Content and Educational/Didactical Resource

This section describes an ontology that represents digital or non-digital resources such as books, articles, chapters, whiteboard teacher annotations, and so on. It is based on the OASIS DocBook specification that contains a large set of content terms (about 380 terms and 3053 entities) with several book structures and relationships (DocBook, 2003). OASIS-DocBook is a not-for-profit, global consortium that drives the development, convergence and adoption of e-business standards and produces worldwide standards for security, Web services, XML conformance, business transactions, electronic publishing, topic maps and interoperability within and between marketplaces.

The concepts used in this ontology specify the components (blocks) of contents and the structures needed to create a learning object. Examples of components are: paragraph, table, figure, slide, animation, and so on. These components could be used to create a more general structure, such as chapter, which together with other structures could be compose a book. The highest level structure is a set that could be constituted by several books and the lowest level is a block. The reason of this is because the definition of fragment is very complex and it is out of EUME Onto purpose. In the foregoing activity example, the teacher may be uses Slide, Animation and WebSite during its explanations and the students may use Movie or Articles for learning. The figure 3 is a part of this ontology and it shows all the concepts and relationships needed for this activity example (referred above).

### 4.3 Hardware Resource Ontology

The Hardware Resource Ontology describes the electronic resources needed to supports the learning process. We have extended the Foundation for Intelligent Physical Agents (FIPA) (FIPA 2003) devices ontology with the devices introduced in the EUME project (personal assistants, projectors, etc.). We have used the FIPA ontology as the basis of our ontology, because of it is a standard for the interoperability of heterogeneous software agents.
Figure 3: An excerpt of the Contents and Didactical/Educational resources ontology.
This ontology is necessary to allow agents to access to educational resources such as projectors, electronic whiteboards, personal assistants, video cameras, audio resources, and so on. In the example presented in section 3, the teacher could be using the projector to present the film and the learners could be using the PDAs to access the teacher annotations generated by Mimio, for example (Figure 4).

In order to reduce implementation efforts, this ontology has been developed in the WebODE platform (WebODE, 2003), a scalable and integrated workbench for ontological engineering that enables the creation of the database in which the ontology will be stored. Furthermore, it facilitates a direct access from the EUME system software components to the ontology contents, attributes and relationships through the Open Knowledge Base Connectivity (OKBC) protocol.

5. Discussion and Future Work

This ontology represents a common language for message syntax among agents, required for the operations communications of the EUME system. During the development of this work we founded another related works with our research's goals: (1) Kabel (1999); (2) Barros (2002); and (3) Sancho & Manjon (2002). However, these works fail into interoperability or pedagogical flexibility issues. The first and the second ones are pedagogically specifics (Technical Manuals or CSCL supports only) and the third makes an evaluation about the power of use of LOM metadata and IMS-EML specification. The EUME Onto, meanwhile, integrate learning design, contents and hardware resources aspects within an ontology, using educational metadata standards/specifications. Furthermore, we believe that this ontology can be re-used by other educational systems in a wide range of teaching/learning methodologies.
We are currently introducing the axioms in order to complete the definitions of this ontology and as a next steps, we have planned to construct the knowledge database using WebODE in the EUME system.

**References**

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