*Journal of Universal Computer Science, vol. 11, no. 9 (2005), 1470-1481*
*submitted: 15/2/05, accepted: 30/7/05, appeared: 28/9/05 © J.UCS*

# Semantic Web Technologies Applied to e-learning Personalization in <e-aula>

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**Abstract:** Despite the increasing importance gained by e-learning standards in the past few years, and the unquestionable goals reached (mainly regarding interoperability among e-learning contents) current e-learning standards are yet not sufficiently aware of the context of the learner. This means that only a limited support for adaptation regarding individual characteristics is currently being provided. In this article, we propose the use of semantic metadata for Learning Object (LO) contextualization in order to adapt instruction to the learner's cognitive requirements in three different ways: background knowledge, knowledge objectives and the most suitable learning style. In our pilot e-learning platform (<e-aula>) the context for LOs is addressed in two different ways: knowledge domain and instructional design. We propose the use of ontologies as the knowledge representation mechanism to allow the delivery of learning material that is relevant to the current situation of the learner.

**Keywords:** Hypermedia systems, Web-based services, XML, Semantic Web, Multimedia
**Categories:** H.3.1, H.3.2, H.3.3, H.3.7, H.5.1

## 1 Introduction

E-learning standards are now starting to have a real impact in the Web based field of education. Their use is not only widely extended in pilot and institutionally funded experimental applications, but many commercial platforms such as WebCT or Blackboard are beginning to be partially compatible with some of the standardization proposals as well. Nevertheless, most of the efforts made and the goals achieved deal with content interoperability (learning objects –LO-, assessment and course packaging). Under current standards and practices, valuable information needed for adapting learning to individual characteristics cannot be easily harvested [Rodriguez, 03].

Therefore the question is, how can we make e-learning aware of the individual characteristics of the learner? How can we adapt a pedagogical e-learning strategy that best fits an individual in a standard way or, at least, in a standard compatible way? This paper proposes an approach to the annotation of LOs, which is based on open standards such as Learning Object Metadata (LOM [IEEE LOM, 02]) and semantic web related technologies, such as knowledge representation by ontologies and Resource Description Framework (RDF [W3C RDF, 04]).

The long term goal of our <e-aula> project is to dynamically generate on-line personalized learning through the assembly of atomic learning assets into coherent learning activities based on the following learner cognitive particularities: background, objectives and learning style. The idea is to select and combine LOs at runtime to generate a personalized course. To make this goal feasible, the first step is to annotate LOs with more profound information in two different areas:

- Pedagogically relevant information to capture the instructional function of a LO. This kind of information will enable LOs to have a description from a teaching and learning perspective, an aspect which is not yet fully covered by e-learning metadata standards. The *educational* category of LOM allows a description of resources from an instructional perspective with values provided by a list (including *Diagram, Figure, Table, Exercise, Narrative, Text* and *Exam*), thus it does not take into account any inherent structure that may exist among the different terms. Even more critical is that types of LOM mix instructional and technical information, and hence should be separated [Ullrich, 2004].
- Context domain information. Metadata about the content of a learning resource would provide for better search results.

In this paper we propose the use of two different ontologies to capture, on the one hand, the instructional function of a LO and, on the other hand, the context of the knowledge domain the LO belongs to. This kind of representation offers the well-known advantages of ontologies: it can provide humans with a shared vocabulary and can serve computers as the basis for semantic interoperability.

This paper is structured as follows: in section 2 we present the general architecture of how personalization is addressed in the <e-aula> system. The processes and the system components involved in the adaptation mechanisms are also described. In section 3 we describe the adaptation logics of the system in more detail. In section 4 some related works are described. Finally, conclusions and future work are presented in section 5.

## 2 <e-aula> Architecture for Personalization

<e-aula> is a research e-learning platform that aims to assist final users in the various processes involved in the e-learning experience (for more details about <e-aula> see [Sierra, 05] or [Sancho, 04 b]). This platform covers the whole process from content creation to its final presentation to the learner. In addition, several tools are being developed to assist the different steps involved in this global process.

The system's objectives are:

- From the learner's perspective, to dynamically deliver personalized content to the learner's cognitive characteristics in terms of his/her knowledge goals, his/her previous knowledge and his/her most suitable learning style.
- From the content author's perspective, to assist the course creation process enabling reusability of existing learning materials and making LO selection easier according to pedagogical criteria.

The <e-aula> architecture addressing personalization features is based on the following pillars (a similar approach is described in [Schmidt, 04]):

- Breaking down courses into modular units (i.e. learning objects).
- Modelling the LO context. The model of the LO context that is addressed in <e-aula> through the use of two different ontologies, includes:
  - (a) The pedagogical context, which means the instructional functionality of the LO from a teaching and learning perspective.
  - (b) The knowledge domain of the LO. In <e-aula> this domain is initially restricted to programming languages.

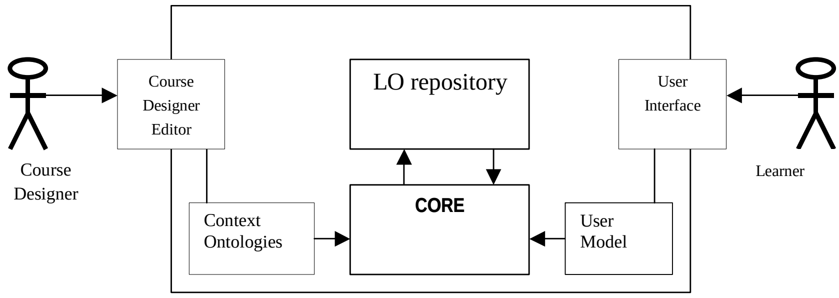


*Figure 1:<e-aula> Overview of Personalization Architecture.*

- Annotating learning objects with pedagogically relevant information, using e-learning standards when possible (e.g. LOM) and the terms of the ontologies to make semantic and didactical relationships between learning objects explicit according to the context domain and the instructional design of the course. This additional information has to be standard compatible.
- Employing user modelling techniques to obtain different learner models or profiles according to which personalization might occur.
- Adapting the learning content to fit the user context using learner model information and the semantically rich metadata associated with learning objects.

A general overview of the system's personalization architecture is shown in Figure 1.

The system deals with LOs, which in this context are defined as the minimal units of pedagogically reasonable learning content (like text, pictures, animations, examples…) and the metadata that describe them. As a part of the <e-aula> project, a personalized course will be built for a learner through a set of these LOs. This is carried out in accordance with the learner's objectives and cognitive peculiarities by using a metadata driven approach. We are using a restricted set of LOM categories plus some extensions that are required by our personalization goals. These extensions are defined by two different ontologies: the pedagogical ontology and the context of the knowledge domain.

Based on the information provided by the ontologies and the user profile elaborated by the user modelling process (Figure 2), a personalized course will be created. The instructional design of the personalized course is modelled according to

IMS Learning Design specification [LD, 03] and covers the most suitable learning style according to the Felder-Silvermann classification [Felder, 88] and the learner's knowledge objectives. The final step for the adaptation process is to equate the learning content with the learner's prior knowledge. This content adaptation is made by XSLT transformations of LO content. A further description of all these processes is given in section 3.

## 3 The Ontology Driven Personalization Approach in <e-aula>

Personalised learning systems bear the potential to meet the requirements of the knowledge society for high quality education and training [Brusilovsky, 99], because they are capable of automatically adapting to the changing attributes of the learning experience. The adaptation logic of a personalised learning system can be defined in the following terms [Karagiannidis, 04]:

- The determinants: the aspects of the learning experience which drive the adaptation. What is the adaptation based on?
- The constituents: the aspects of the learning experience that are subject to adaptation. What is being adapted?
- The rules: the logics which define which constituents are selected for different determinants.

In the following sub sections these three aspects of the <e-aula> system are addressed.

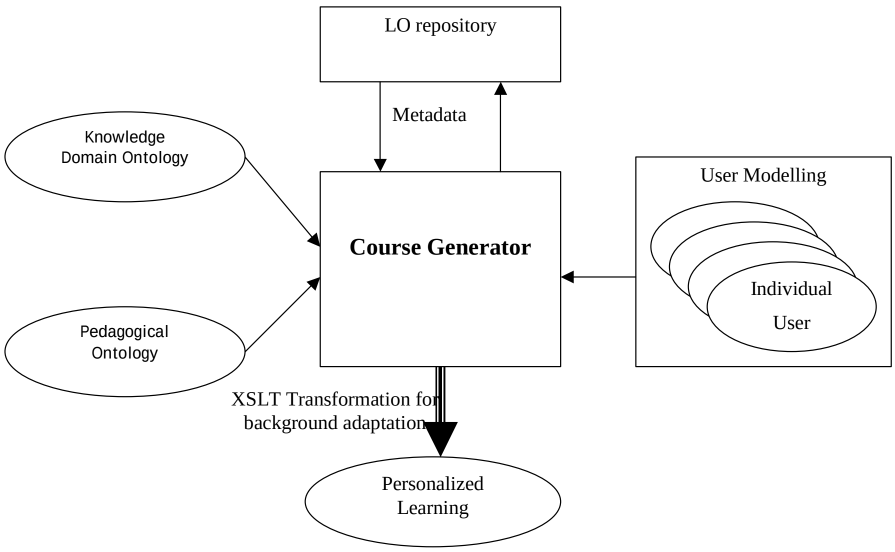


*Figure 2: Adaptation process in <e-aula>*

### 3.1 <e-aula> Adaptation Determinants

In <e-aula> we consider three different aspects of the learner cognitive particularities for adaptation:

#### 3.1.1 Learner knowledge goals

Our long term goal is to offer the learner a competency-based e-learning experience according to a life-long learning educational paradigm [Koper, 04b].

Depending on the learner's knowledge objectives, very different pedagogical strategies need to be applied. In <e-aula> we are initially considering only three different objectives and we are using IMS LD for instructional modelling (see section 3.3 for further details):

- Quick overview. In case the learner wishes to obtain a quick overview of a topic or get a global idea.
- Average. All the concepts are exposed together with several examples and some additional material to give the learner the opportunity of gaining what we consider is just an intermediate level of knowledge.
- Expert. In case the learner wants to gain a full understanding of the topic, all the concepts plus all the additional material including examples and simulations are accessible to the learner.

| Learning Dimension | Learning Style 1 | Learning Style 2 |
|---|---|---|
| **Perception** | **Sensing:** Concrete and practical, oriented toward facts and procedures. | **Intuitive:** Conceptual and innovative, oriented toward theories and meanings |
| **Input** | **Visual:** Prefers visual representations: pictures, diagrams, flow charts. | **Verbal:** Prefers written and spoken explanations. |
| **Organization** | **Inductive:** Prefers representations that proceed from the specific to the general. | **Deductive:** Prefers presentations that go from the general to the specific. |
| **Processing** | **Active:** Learns by trying things out and working with others. | **Reflective:** Learns by thinking things through, generally working alone. |
| **Understanding** | **Sequential:** Linear and orderly, learns in small incremental steps. | **Global:** Holistic and system wide thinkers, learns in large steps. |

*Table 1: Learning Dimensions and Styles in the Felder-Silverman Style Model [Sharda,03]*

#### 3.1.2 Optimum learning style

We have adopted the Felder-Silverman model for learning style categorization. Given the variety of learning style theories and models that are available in the literature (for an overview see [Karagiannidis, 04]), we need to determine which is the most appropriate for our system. We have chosen the Felder and Silverman model for a number of reasons, the most important being: first, because this model was specifically conceived and tested for Engineering Education, the context which

<e-aula> is aiming at. And second, because the Index of Learning Styles by Felder and Silverman provides a simple five-way classification mechanism for learning style estimation based on the administration of a 44 item questionnaire. Therefore, the assessment mechanism available for the model is quite reasonable in terms of:

- Time. As the profile for the learner is determined by the initial questionnaire, the student has to be able to complete it in a reasonable time and with limited effort.
- Cost effectiveness. This is one of the basic goals of the whole <e-aula> application.

In the Felder-Silverman model, learning styles are classified over five dimensions; each with two options as shown in Table 1. Most individuals tend to have a dominant learning style in each dimension, depending upon their personality.

#### 3.1.3 The Learner's background knowledge

<e-aula> classifies learners into five different categories depending on their previous knowledge:

- Beginner, novice, intermediate, advanced, expert.

The last criterion (learner background) is considered a short-term modelling characteristic as it attempts to model one aspect that will change during course interaction. In <e-aula> we use a combination type for this particular kind of user modelling process (short term modelling). This means the student is categorized initially by a stereotype and then the stereotype is gradually complemented as more information is acquired from the student's interaction with the system.

The first and second criteria (learning objective and optimum learning style) are considered as long-term modelling aspects and they will be updated mostly under learner control.

The learner modelling process makes short and long term modelling and stores this information in a standard compatible way as part of the Learner Information Package [IMS LIP, 05] record. <e-aula> maps this information to the data of LOs metadata, resulting in a ranked list of the most suited learning objects for a specific profile.

### 3.2 <e-aula> Adaptation Constituents

The <e-aula> adaptation constituents are the learning objects. The size and scope of each piece of learning content that are combined to form a personalized course is a key consideration here. Better adaptation and reuse of learning objects may be obtained using fine-grained learning objects (a paragraph or a diagram size) as the flexibility for the creation of additional content packages increases. Nevertheless, the smaller the objects are, the greater the annotation effort implied.

To cope with our personalization objectives and still maintain a cost effective system, <e-aula> learning objects are self-contained units designed to be instructionally independent: this means they aim to teach a particular concept or ability. We have solved the flexibility-annotation trade off by defining two levels of adaptation:

### 3.2.1 Intra learning object level

This is the way the system adapts information to suit the prior knowledge and the learner's knowledge objectives.

In <e-aula> all the basic course contents are represented in XML and not in HTML as happens in most e-learning systems [Sancho, 04]. When a specific content is accessed from the webserver an XSL transformation is applied to the content and an HTML is delivered to the web client. In addition, XML also gives us the possibility to generate other output types of lessons such as PDF versions. Additionally, our marked LOs enable the adaptation of the content itself, using a basic concept of level of detail.

### 3.2.2 Inter learning object

This is the adaptation mechanism used to tailor the learning experience to the learning style that best suits a specific learner.

By re-sequencing the learning content in the package, or by adding additional content, or by adding content that supports different learning approaches, the course may be suited to different learning style categories while still supporting a common learning objective and a learner's initial knowledge [Conlan, 02].

A list with a rank of the most suitable learning objects is obtained based on the learner's learning style profile and information associated with the learning object through its metadata record. This information includes a specific entry associated with the pedagogical ontology to identify the kind of educational resource most convenient to a specific learning style and another entry to the concept domain ontology.

<e-aula> learning objects are annotated using a restricted set of LOM categories which turn out to be sufficient to annotate and query our resources (see Table 2), plus two additional terms: one associated with the pedagogical ontology and the other with the concept domain ontology. The corresponding ontology term is expressed through a taxon sub element (see Table 2, 9.2.2).

At this stage of the project, we are using the pedagogical classification proposed by Ullrich [Ullrich, 04] to represent the instructional features needed to identify the resource for a particular learning style adaptation. The different classes of this ontology and the relations among them can be seen in Figure 3. The goal of this ontology is to provide a description of a learning resource from an instructional perspective. Each class of the ontology stands for a particular instructional role the resource can play.

In our personalization architecture, once the learning style type for a learner has been identified, it will be possible to select the most suitable learning objects in a certain context domain for that particular learning style type, according to the ontology classification. For instance, let's say we have identified an Active learner. In order to compose the course, learning objects of the class Interactivity (Exploration, Real World Problems, Invitation….) will automatically be preferred to the ones belonging to the Example class, which will be more suitable for a Reflective learner.

We use RDF [RDF, 04] as the binding technology for annotating our resources. Semantic web technologies, particularly RDF, provide for interesting possibilities. It can be used as a simple ontology language, as well as for describing the resources according to LOM, using the RDF bindings of LOM [Nilsson, 2001]. On the other hand, more powerful ontology languages like OWL [OWL, 04] can be used on top of RDF. OWL also provides for query languages and reasoning rules, further enriching the possibilities of RDF.

### 3.3 <e-aula> instructional design for adaptation

The design of a course involves the definition and the classification of learning goals, the selection of suitable teaching methods and their assembly into a course [Van Merrinboer, 97]. This requires a conceptual representation that explicitly models the relationships among the LOs. In <e-aula> we are using IMS Learning Design specification to address these issues.

| | |
|---|---|
| General | |
| 1.1 identifier | 3.3 Metadata Schema |
| 1.1.1 catalog | 3.4 Language |
| 1.1.2 entry | Technical |
| 1.2 title | 4.1 format |
| 1.4 language | 4.2 size |
| 1.5 description | 4.3 location |
| 1.6 keyword | Educational |
| Life Cycle | 5.1 interactivity type |
| 2.3 contribute | 5.2 learning resource type |
| 2.3.1 role | 5.5 intended user role |
| 2.3.2 entity | Classification |
| 2.3.3 date | 9.1 Purpose |
| Meta-metadata | 9.2 Taxon Path |
| 3.2 contribute | 9.2.1 source |
| 3.2.1 role | 9.2.2 taxon |
| 3.2.2 entity | 9.2.2.1 id entry |
| 3.2.3 date | |

*Table 2: <e-aula> application profile*

IMS LD states that any instructional design can be represented by the following conceptual model (classes are in italics) [Koper, 04]:

> "A person is assigned to a *role* in the teaching process, typically a *learner* or a *staff* role. In this role he or she works towards certain *outcomes* by performing more or less structured *learning and/or support activities* within an *environment*. Which role gets the activities at what moment in the process, is determined by learning design *method* or by a *notification* (triggering mechanism)"

IMS LD describes how a learning design unfolds through the analogy of a theatrical play: the play is presented in a series of acts in which people play roles and undertake a series of activities within the act (for a learner role this might include discussing a problem with classmates or visiting an exposition). An act is completed after all the activities of a specified role or roles, are finished. When one act ends, the next one starts. The play finishes when all acts are completed.

In the <e-aula> model all possible Learner Profiles are represented by sub roles of the role learner (we have created 10 different sub roles to address all the possibilities of <e-aula> adaptation goals: sensing, intuitive, visual, verbal, inductive, deductive, active, reflective, sequential and global). Using the learners' classification we can create different *role-parts* within an *act* that fit in with the learners' learning style, that is to say, we want learners to grasp a learning objective but we model these *role-parts* in a different way for each role so that each learner feels more comfortable.

In the current stage <e-aula> performance is static, which means course structure is predefined. Our long term goal is to develop ontologies for different pedagogical approaches depending on the learning style. This will allow for specific agents to create specific units of learning according to the principles of a certain pedagogical ontology, including the possibility of constructing simple units of their own.

## 4 Related Work

Ontologies have been proposed as a general tool to help to overcome problems in AI and education [Mizoguchi, 00]. More specifically, research on learning object

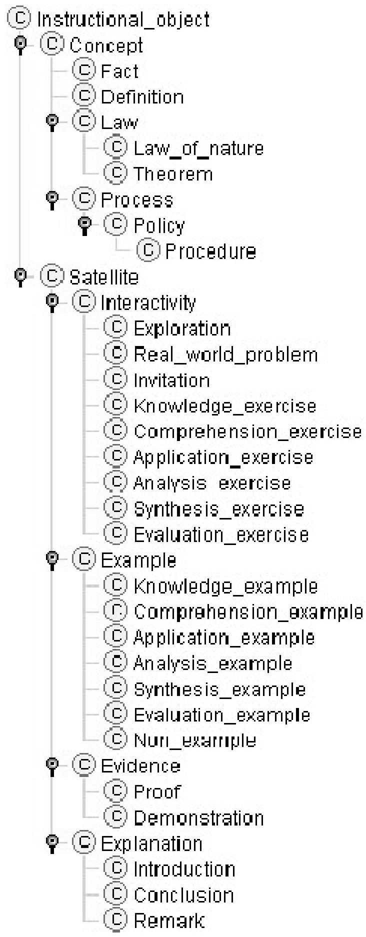


*Figure 3: Pedagogical Ontology [Ullrich, 04]*

technology [Brasse, 03] describes the use of a context domain ontology to enrich LOM with additional attributes. Dolog [Dolog, 04] proposes an architecture for distributed e-learning environments based on semantic web technologies. They describe three different ontologies to undertake the adaptation features: one for describing learning resources, one for describing domain information and another for describing learners with respect to user interests, performance, goals, preferences and so on. None of these represent the instructional function of a resource.

On the other hand [Ullrich, 04] and [Meisel, 03] propose the use of pedagogical ontologies to capture instructional design knowledge. Nevertheless, none of these proposals is specifically oriented to design teaching methods adapted to different learning style models.

The <e-aula> approach combines these two different kind of proposals: we use a context ontology and a pedagogical ontology. Both ontologies will be used to create dynamic personalized courses using IMS LD specification.

## 5 Conclusions and Future Work

Even though learning standards have reached unquestionable goals in terms of interoperability, we think more effort is needed in terms of describing the learning objects context in terms of domain knowledge and the instructional use of the learning objects. This will enable the development of intelligent applications capable of adapting learning to individual characteristics in a dynamic way, and also, to improve reusability of the learning resources by enriching the possibilities for searching.

In this paper we have proposed a standard compatible way of describing learning objects based on ontological representations. The knowledge domain (which for our system is restricted to Programming Languages) can be easily represented by standard ontologies, like the ones proposed by the ACM Computing Classification System [ACM, 98]. Nevertheless no proposals for standards have yet been developed for instructional purposes. We are working with the pedagogical ontology proposed by [Ullrich, 04] to classify our learning resources from an instructional perspective.

Courses in <e-aula> are designed according to IMS LD in a way that permits adaptation according to different learning objectives and styles.

The next step in our <e-aula> project will be to extend the pedagogical ontology to better fit system requirements in terms of the different learning styles and to enable the dynamic generation of simple units of learning.

**Acknowledgements**

The Spanish Committee of Science and Technology (TIC2001-1462 and TIN2004-08367-C02-02) has supported this work.

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