Online Curriculum on the Semantic Web: The CSD-UoC Portal for Peer-to-Peer E-learning

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ABSTRACT

Online Curriculum Portals aim to support networks of instructors and learners by providing a space of convergence for enhancing peer-to-peer learning interactions among individuals of an educational institution. To this end, effective, open and scalable e-learning systems are required to acquire, store, and share knowledge under the form of learning objects (LO). In this paper, we are interested in exploiting the semantic relationships that characterize these LOs (e.g., prerequisite, part-of or see-also) in order to capture and access individual and group knowledge in conjunction with the learning processes supported by educational institutions. To achieve this functionality, Semantic Web (e.g., RDF/s) and declarative query languages (e.g., RQL) are employed to represent LOs and their relationships (e.g., LOM), as well as, to support navigation at the conceptual e-learning Portal space. In this way, different LOs could be presented to the same learners, according to the traversed schema navigation paths (i.e., learning paths). Using the Apache Jetspeed framework we are able to generate and assemble at run-time portlets (i.e., pluggable web components) for visualizing personalized views as dynamic web pages. Last but not least, both learners and instructors can employ the same Portal GUI for updating semantically described LOs and thus support an open-ended continuum of learning. To the best of our knowledge, the work presented in this paper is the first Online Curriculum Portal platform supporting the aforementioned functionality.

Categories and Subject Descriptors

K.3.3 [**Computing Milieux**]: Computers and Education; Computer Uses in Education— Collaborative learning H.3.5 [**Information Systems**]: Information Storage and Retrieval; On-Line Information Systems— Web-based services

General Terms: Design, Management.

Keywords: E-Learning Portals, Semantic Web, IEEE-LOM, Jetspeed Portlets.

1. INTRODUCTION

For the last decade "teacher bandwidth", i.e., the number of learners a single instructor can successfully mentor, has been the primary bottleneck in learning. Accordingly, most of the instructional technology research has focused on automating instructional design and delivery for reducing the creation costs of learning content but also for the benefits that automation may offer in individualizing the instruction process. Nowadays, peer-to-peer learning models provide an alternative approach for removing the instructor bottleneck: instead of replacing the instructor with an intelligent system, replace the instructor with a very large network of learners. These models appear to be quite beneficial in informal learning environments, but the constant expansion of learners especially in higher education institutions makes it mandatory to extend them also in formal learning environments. The functionality (both from a technological and pedagogical viewpoint) of web-based e-learning systems aiming to support such networks of learners and instructors is still in its infancy.

The cornerstone of e-learning systems is the notion of learning objects (LOs) that capture any chunk of learning material regardless of its form, granularity and functionality. By definition LOs encapsulate both learning content and appropriate descriptive information (i.e., metadata). LOs aim to provide self-describing learning material that once developed can subsequently be exchanged, retrieved and reused. The key factor for supporting large scale interoperability, portability and reusability of LOs is the quality of the semantic description of LOs, i.e., its metadata specification [16]. Several e-learning specifications have been proposed in literature like ARIADNE [1], IMS [9] and LOM [8] which are recently encoded using Semantic Web languages like RDF/S [14, 19].

In this context, an Online Curriculum aggregates LOs at various granularity levels (programs, courses, modules, lessons, etc.) using e-learning-specific semantic descriptions while offering a uniform web-based access to the available Portal LOs. We believe that the semantic relationships of LOs (e.g., prerequisite, part-of, or see-also) captured by the majority of metadata specifications [15] have an important pedagogical value when learners browse or query the LOs of an Online Curriculum Portal. Semantic relationships of LOs have essentially two spaces: The inner space, which implies the LO structure, and the outer space, which delivers the learning value of LOs within specific contexts of use. Both kinds of relationships enable the specification of suitable learning paths within the Portal, as sequences of semantically interrelated LOs that a learner may follow in order to grasp a particular topic. Learning paths in an Online Curriculum can span multiple lessons, modules, courses or even programs allowing learners to access on demand LOs that best fit their learning needs. In a nutshell, these paths can be used for personalizing the Portal information space to learners' needs, thus providing a richer and more complete online learning experience.

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During the specification of the Portal functionality for the Computer Science Department of the University of Crete (CSD-UoC: www.csd.uoc.gr), we have identified three distinct roles of potential users with accordantly different needs for accessing and updating the content or the semantic description of LOs:

- *Instructors*, who can freely insert, delete and modify LOs. Furthermore, they are able to customize the quality (i.e., schema) and quantity (i.e., data) of the LOs' descriptions related to their courses, as well as to provide for each LO its semantic relationships with others LOs in the same or different courses;
- *Learners*, who can not only browse or query the LOs of the Portal but they can also insert new LOs or enrich the description of existing LOs in order, for example, to extend the available learning paths for a course. Moreover, they can annotate existing LOs thought the Portal discussion forums;
- *Administrators*, who can provide basic information about the people and courses involved in the Online Curriculum, required for the initial startup of the portal, and they are responsible for defining the appropriate access rights for each user role.

It should be stressed that the aforementioned user roles are related to appropriate *semantic views* over the Portal information space, which are presented as standard web pages (for navigation) and forms (for updates). These views essentially specify the parts of the e-learning schema(s) related to the learning material that a particular user role is authorized to access. Consider, for instance, the following scenario conceptualizing and integrating individual with group activities in the context of the learning processes supported by our department. Assuming that *instructor* I_1 is responsible for *course* C_1, the Portal *administrator* will have to firstly insert both I_1 and C_1 using the administration views and then to grant to I_1 the appropriate rights for inserting/modifying/deleting LOs related to C_1. After acquiring the appropriate credentials, I_1 can directly employ or choose to modify the default views associated with the management of the current course C_1 to insert/modify/delete related LOs. In the first case, I_1 can insert a *course lecture* CL_1 as part of C_1 (through *part-of*) and relate (through *see-also* or *prerequisite*) it eventually to another *course lecture* CL_2, thus, creating a first learning path. Subsequntly, a learner L_1 selecting *course* C_1 can navigate to *course lecture* CL_1 and can follow the predefined learning paths to discover other LOs like CL_2 related to C_1. Note that the LOs browsed each time depend on the current navigational context of learners specified both at the schema (i.e., the chosen semantic relationships) and data levels (i.e., the chosen LO). In addition, learners are able to insert annotations (through appropriate posts) or to enrich the descriptions of already visited LOs. For instance, learner L_1 can extend the predefined by I_1 learning paths with new LOs which become available to other learners as long as they are related to at least one of the existing LOs in the Portal. In the second case, an instructor (e.g., I_1) can customize the descriptions of the offered LOs by excluding (or enriching) the parts of the e-learning schema(s), that learners are authorized to navigate, annotate or update.

The CSD-UoC Online Curriculum Portal presented in this paper builds on the SeLeNe (http://www.dcs.bbk.ac.uk/selene/) project experience and addresses successfully the functionality requirements presented earlier. More precisely, our Portal infrastructure:

- Exploits the semantic relationships of LOs in order to support conceptual navigation and retrieval of LOs through specific views of e-learning RDF/S schemas. In particular, sequences of semantically interrelated LOs (e.g., *prerequisite*, *part-of*, *see-also* relationships) may be traversed by learners in order to grasp a particular topic.
- Supports personalization of LOs' descriptions for both instructors and learners. The former can easily specify the parts (i.e., the views) of the e-learning schemas employed by the Portal that are more adequate for the description of their LOs. The latter have the ability to use the specified views in order to either follow predefined learning paths between LOs or enrich them by inserting and describing new LOs.
- Offers a uniform web based interface for both browsing and updating the content or the semantic description of available LOs according to the Portal RDF/S schemas.

In order to provide this novel functionality, two key open-source technologies are used:

- The ICS-FORTH RDFSuite (http://139.91.183.30:9090/RDF/) of tools for validating, storing and querying RDF/S schemas and resource descriptions while ensuring scalability and efficiency when accessing large volumes of LO descriptions. In particular, the expressiveness of the declarative RDF/S Query Language (RQL) [12] is crucial for specifying on demand personalized views in order to navigate and update LOs using the Portal RDF/S schema(s).
- The Apache Jetspeed framework for constructing at run-time portlets (i.e., pluggable web components) and generating on the fly the dynamic HTML pages visualizing learners' or instructors' personalized views.

To the best of our knowledge there is no other Online Curriculum effort that provides networks of learners and instructors with such unique and powerful features. The remainder of this paper is organized as follows: Section 2 introduces the core RDF/S classes and properties employed to describe LOs in our Portal, as well as to define and explore appropriate leaning paths. Section 3 describes the querying and updating functionality we have implemented according to the employed RDF/S schemas. Section 4 outlines the architecture of our Portal, while Section 5 compares our Portal infrastructure with related work. Finally, Section 6 concludes our paper and discusses future research directions.

2. SEMANTIC MODELING OF ONLINE CURRICULA

As discussed in the previous section, an integral part of an Online Curriculum Portal is the employed metadata specifications. In this respect, we have extended the IEEE LOM [8] (Learning Object Metadata) RDF/S [14, 19] schema provided by the Selene project, so as to support fine-grained semantic descriptions of LOs. As a matter of fact, multiple RDF/S namespaces were used to support a modular and extensible Portal schema definition. In this context, the general, technical, or educational characteristics of LOs, are represented by distinct namespaces capturing the corresponding LOM metadata categories. Other RDF/S schemata, like vCard [18], are also employed in order to support detailed people's descriptions associated with the LOs accessible by our Portal.

More precisely, our Portal schema relies on the notion of the *learning object* (*LO*) as the root of the inheritance hierarchy of all LOs classes (see Fig. 1) represented by an Online Curriculum. In this way, *LO* subclasses inherit as usual attributes with

information about their content (*Title, Subject*, *Date, Language*, *Format, File,* etc.), as well as, their pedagogical value (educational *Context* and *Level*, *Learning_Objectives* and *Time*, etc.). In this context, we classify LOs under two broad categories according to the role they can play in the learning processes supported by our Portal. On one hand, we can consider classes of LOs to be "mandatory" – in a loose sense of the term – for successfully accomplishing the learning objectives specified by a Curriculum. These classes include the *Program* representing an entire graduate or undergraduate program of studies to which learners have to subscribe, the *Course* usually defined in a credit based educational system as a part of a *Program*, the *Module* capturing the part of a course aiming to address high-level learning objectives, the *Lesson*, which can be part of a *Module*, capturing the part of a course related to detailed learning objectives, as well as various kinds of *Assignment*s representing (as subclasses of the *Component* class*)* homework assigned to learners assisting a course. On the other hand, we can consider classes of LOs to represent, in a broader sense, *Supporting Material*, i.e., supporting learners in their self-study. These classes include *Books, Online Resources, Software*, etc., and they are also represented as subclasses of the *Component* class. The above partitioning of LOs classes, enable us to refine the RDF/S specification (i.e., the domain range classes) of the LOM semantic relationships of LOs like *prerequisite*, *part-of*, or *see-also*, as well as, to enforce appropriate consistency rules when updating LOs' descriptions. In particular, LOs of the former category can be inter-related only through *prerequisite* and *part-of* relationships while they can be related with LOs of the latter category only through *see-also.* Finally, LOs can be associated with their providers (*Persons* and/or *Institutions)* through the relationships *creator* or *contributor*.

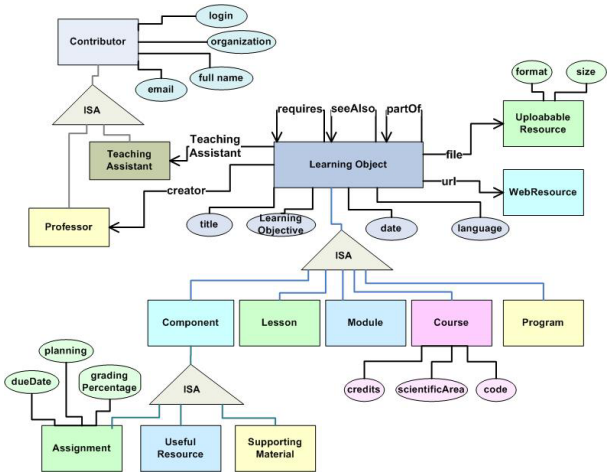

Fig. 1 Overview of the Online Curriculum RDF/S schema

Furthermore, since the LOs accessed through an Online Curriculum are not always physically stored in the Portal, we distinguish between the URI of a LO employed by its RDF/S description (and generated automatically by our Portal) and its physical location on the web (*Web_Resource* class) or the Portal file system (*Unloadable_Resource* class). For example, LOs classified under the *Book* or *Online_Resource* classes need only to be described using their *URL*s on the web instead of the *file* names used to upload LOs like *Lecture*s.

It is worth noting that despite our efforts for a modular, extensible and intuitive RDF/S schema design, the Portal information space one has to master still remains incredibly rich. Hence, LOs' providers may encounter difficulties when inserting or modifying LOs' descriptions due to a misleading or even erroneous understanding of the LOs' semantics. For this reason, we decided not to expose LOs' providers directly to the entire RDF/S schema of our Portal, but instead to specify and visualize appropriate semantic views on top. These semantic views correspond to Portal LO categories and subcategories, as shown in Table 1. To each one of these (sub)categories corresponds a different level of detail thus allowing the course's customization by the involved instructors. By choosing a (sub)category as enabled (or disabled) an instructor actually permits (or forbids) access to the corresponding RDF/S schema view and in turn the associated resources. The correspondence of categories/views with the RDF/S classes of the Portal schema is also illustrated in Table 1. Finally, by enabling a specific view, the subsuming views corresponding to LOs' subclasses become also available. In this way, instructors are able to decide which of these views will be used for describing and accessing the LOs involved in their courses. LOs cannot be inserted, updated or retrieved by learners unless the instructor enables the corresponding view, ensuring the integrity and consistency of LOs' descriptions across browsing, querying and updating tasks of an Online Curriculum Portal.

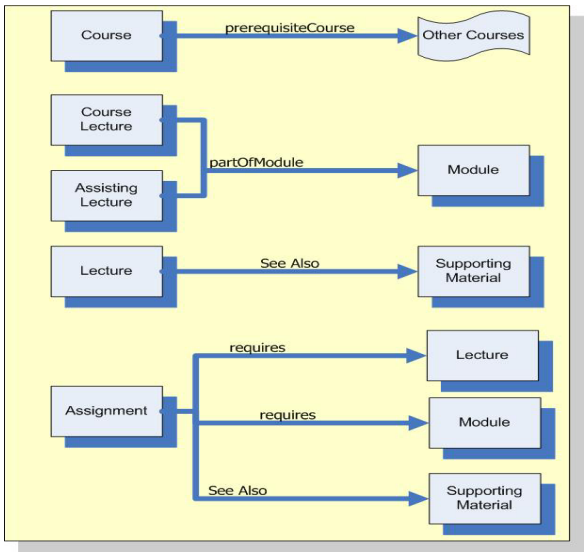

Fig. 2. Semantic Relationships of LOs

The RDF/S schema presented in this section intends to represent a semantically rich information space for describing and relating LOs without at the same time complicating Portal access and management. Allowing LOs to reside physically outside the Portal opens the scope of an Online Curriculum to vast amounts of online web resources, under, of course, the assumption that they can be sufficiently described using the Portal schema. Partitioning the available schema classes of LOs, as mandatory or supporting learning material, is expected to facilitate both instructors and learners to better grasp the Portal e-learning conceptual space (i.e., LO semantic relationships). Providing a per course personalization mechanism of the schema intends to address information overload issues by simplifying the LO description and updating tasks.

2.1 Semantic Relationships

One of the novel features of our Portal is its ability to exploit the available relationships defined among the LO classes in order to

implement conceptual navigation and retrieval. Thus, learners are not obliged anymore to navigate back and forth or issue full text queries in order to find a specific LO, but instead they can explore the already established semantic relationships to contextually access LOs in the Portal. In this way, instructors (or peer learners) can easily lay out learning paths that one might follow to grasp the topics of a particular course. We believe that the semantic relationships of LOs play a crucial role especially in peer-to-peer learning environments where networks of instructors and learners have the ability to freely insert or modify LOs and their descriptions while at the same time they are striving for a meaningful and consistent access to Online Curriculum Portals. Fig. 2 illustrates the semantic relationships of LOs in our RDF/S schema refining the *prerequisite*, *part-of*, and *see-also* relationships of the IEEE LOM metadata specification [8]. More specialized relationships (e.g., rhetoric like *explains*) could be defined by the instructors upon request to the Portal administrators.

For example, a learner L_1 starting from a *Course* can navigate through the *prerequisiteCourse* relationship and retrieve LOs belonging to the target prerequisite course(s). Alternatively, L_1 can choose to visit a *Course Lecture*, where (s)he can discover whether another *Lecture* or a *Module* is required to fully understand the content of this lecture. But L_1 can also find out whether this *Lecture* is required for any *Assignments* that (s)he has to fulfill in order to successfully assimilate *Course* material. In this context, we can consider *prerequisiteCourse* and *requires* as "strong" relationships, literally forcing a learner to follow a specific learning path while *partOfModule* and *SeeAlso* are rather "weaker" relationships suggesting a path but not forcing learners to follow it. It is under the instructor's responsibility to decide which of them should be employed along with the LOs inserted in the Portal. It should be stressed that in order to operate properly our Portal does not require any of the LOs' relationships. However, by discarding the semantic relationships of LOs the whole effort is reduced to a typical e-learning web site with none of the powerful features of the Online Curriculum Portals presented in this paper.

2.2 Learning Paths

Following the Web tradition, learning paths within the Portal are essentially represented as sequences of semantically interrelated LOs that a learner can follow so as to grasp a particular course's topic. Learning paths can either be preset by the instructor or devised by the learners as they enrich the semantic relationships of Portal LOs. The LOs accessed each time depend on the current navigational context of learners specified both at the schema (i.e., the chosen semantic relationships) and data levels (i.e., the chosen LO). Thus, different LOs could be presented to the same learners, according to the actually traversed semantic relationship originating from the same LO. In a nutshell, these paths can be used for personalizing the Portal information space to learners' needs, thus providing a richer and more complete online learning experience.

For example, we assume that a learner L_1 is interested in **Course CS359** as depicted in Fig. 3. Then, L_1 chooses to access the *Module* named "**Client-Side Architectures**" and follow the *partOf* relationship to *Course Lecture* "**Client-Side Development**". Given that to fully understand the topic of this particular *Course Lecture*, learners should have background knowledge of "**Java RMI and Serialization**" the instructor has specified the corresponding **CS252** lecture as a *prerequisite* LO. Through this relationship learner L_1 accesses the description of this particular *Course Lecture*, and discovers that an interesting *Assisting Lecture* on "**Java Applets**" is available and relevant to (her)his self-study. So, even though this LO was not initially included by the instructor in the learning path of *Course* **CS359**, learner L_1 discovers a lecture that fits better his own needs by traversing the existing LO semantic relationships. Another learner L_2 following the same learning path insofar may instead judge that the required *Course Lecture* on "**Java Exception Handling**" is more useful for her/his homework. Then, (s)he may traverse the corresponding learning path and access the associated *Source Code* example "**Throw_Demo.java**".

Table 1. Portal semantic views/categories and their corresponding RDF/S schema classes

Portal Main View/ Category	Portal Subcategory Level 1	Portal Subcategory Level 2	RDF/S Schema Class
General Information			Course
Course Objectives			Course
Grades			Course
Announcements			Announcement
Lectures	Course		Course Lecture
	Assisting		Assisting Lecture
	Supplementary		Supplementary Lecture
Assignments	Homework		Homework
	Laboratory		Laboratory
	Project		Project
	Online Test		Online Test
Exams	Midterm		Exam
	Final (1st Period)		Exam
	Final (2nd Period)		Exam
Supporting Material	Books	Main	Main
		Additional	Additional
	Papers	Journal	Journal
		Conference	Conference
	Programming Examples	Executable Code	Executable Code
		Source Code	Source Code
	Handouts		Handout
	Tutorials		Tutorial
	Manuals		Manual
Useful Resources	Software		Software Link
	Online Courses		Online Course
	Research Projects		Research Project
	FAQs		FAQ

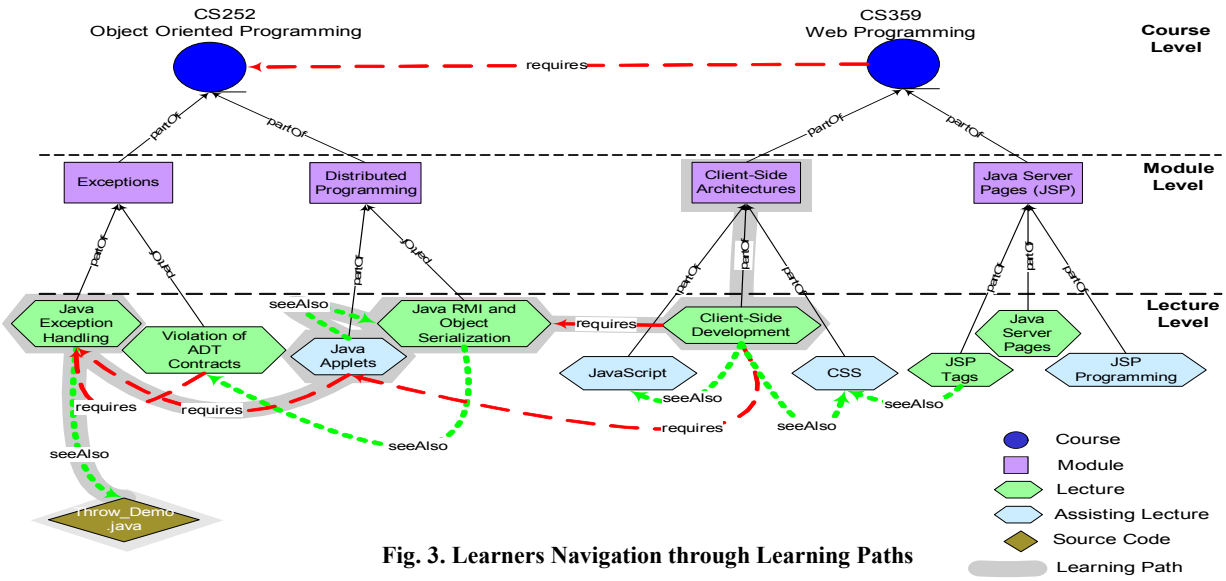

Fig. 3. Learners Navigation through Learning Paths

It becomes obvious that other learners could follow quite different paths even completely ignore the path(s) specified by the instructor of **CS359**. The opportunities for learning more and new things in different ways from day to day are considerably increased when learners are provided with the ability to insert and semantically describe new LOs found, for instance, on the web.

3. QUERYING AND UPDATING ONLINE CURRICULA

Our Online Curriculum Portal relies on the translation of the users' (administrators/instructors/learners) navigation into appropriate RQL queries. These queries capture the specific browsing or querying actions of a user along with their navigation history inside the Portal. RQL expressiveness enables us to formulate the adequate complex queries so as to retrieve LOs matching the filtering criteria (at the schema or the data level) set by a learner. So for every possible browsing or querying action a corresponding RQL query is generated on the fly using the schema (i.e., classes and relationships) and the data (i.e., LOs) information of the accessed Portal views. The results of RQL queries are presented to the users by dynamically constructed web pages, which encapsulate the RQL queries required to continue their browsing/querying in the Portal by taking into account the history of already performed actions. Furthermore, insertion, modification or deletion of LOs in the Portal is implemented using the RDFSuite Update API. More precisely, the multimedia content of LOs is stored under the file system while their semantic descriptions are updated into the RSSDB Store. Once again RQL queries are used to retrieve the available semantic descriptions of the LO currently been modified. Finally, *ad hoc* queries are also supported using appropriate query forms as for updates.

3.1 RDF/S Queries

Learners are allowed to browse and update the part of the Portal RDF/S schema for a specific course that the instructor has chosen earlier, i.e., according to the selected views/categories. Learners can login either as anonymous users, without any insert/update capabilities (depending on course policy some extra access restrictions might apply) or as registered users having full access privileges to the Portal functionality. All users will start from the Portal's default pages so as to choose the program and course they are interested in and then they will be transferred to the course's initial page. Learners can browse around either by choosing a starting point from the categories menu or by selecting one of the associated LOs or even by using standard back and forward buttons of the web browser. Learners are presented with an intuitive web interface that gives them access to the Portal LOs. The navigation is based on constructing and executing adequate RQL queries for every browsing action. More on translating the user navigation actions to RQL queries can be found at [3].

3.2 RDF/S Updates

Users (administrators/instructors/learners) are able to insert/modify/delete LOs or their descriptions according to the attributed credentials and the semantic views offered by the Portal. Instructors are responsible for choosing which views/categories will be made available for the specific course, thus, enabling LOs that fall under a certain category to be inserted. Based on these views, each time a LO is inserted, modified or deleted, narrower views are specified by employing web forms. These forms visualize the corresponding class definitions and load the existing attribute values or relationships of a specific LO. Consequently, the instructor or the authorized learner is able to inspect the existing semantic descriptions of the LO at hand. It should be also noted that the association of two LOs requires their prior existence in the Portal. Thus, the deletion of one of them results to the automatic deletion of the corresponding relationship. The Portal undertakes the responsibility of preserving LO descriptions in a consistent state according to the schema part specified in the enabling view while informing users about the effect of each performed update action. The existence of schema-based views for each update web form ensures a logical/view data independency of the Portal resources.

For example, let us assume that an instructor wishes to insert a *Course Lecture*. Firstly, (s)he needs to ensure that the corresponding view has already been enabled and then to employ the appropriate update form provided by the Portal (Fig. 4b). From this point on, an instructor or a registered learner is able to fill the values of the attributes foreseen by the Portal schema for the involved LO class and associate the newly inserted LO with others using one of the available semantic relationships. When the whole update process is completed, the description of the new LO is inserted into the RSSDB Store in order to be subsequently accessed by other instructors or learners.

4. CSD-UoC PORTAL ARCHITECTURE

In this section we will present the overall architecture of the CSD-UoC Online Curriculum Portal we have developed and implemented, and discuss various design decisions. In order to build the user interface, we rely on the Apache Jetspeed Portlet Framework and RDFSuite RQL queries, which are executed against so as to retrieve the corresponding RDF/S descriptions of LOs. In the sequel, we will detail how the user's navigation is translated into RQL queries which are evaluated against an RSSDB database holding the RDF/S descriptions of LOs in PostgreSQL. We will also present the translation into HTML of the obtained RQL query results at each navigation step using the Apache Jetspeed Portlets and associated JSP and XSL files.

4.1 Apache Jetspeed and Portlets

Apache Jetspeed (http://portals.apache.org/jetspeed-1/) is an open source framework for the creation of dynamic portals based on a standardized portlet API. This framework provides the necessary tools to deploy and manage portlets. A portlet is a software component responsible for the creation of a specific part of the web page under consideration. After the construction of the HTML page parts, Jetspeed provides the mechanism (through the Turbine framework, which is mainly based on the use of PSML configuration files) so as to assemble at run-time an entire HTML page visualizing the personalized view of the specific user.

Portlets are registered components of the framework and can be used in any order and combination to construct a web page. Each user role in Jetspeed is associated with one or more portlets. When Jetspeed authenticates a user then its corresponding portlets are "loaded", i.e., are performing the necessary actions to construct the dynamic web page to be presented. Each portlet in our Portal has an associated JSP (Java Server Pages) file that is executed in order to generate the portlet's contents. JSP are automatically translated to servlets through the servlet container employed to run through the servlet container employed to run Jetspeed inside, e.g., Apache Tomcat. In our Portal, since each user's navigation is translated into an RQL query, we additionally need a way to interpret the returned RDF/S results. This is done by using the appropriate XSL (eXtended Stylesheet Language) [11] transformations' file, so that RDF/S described resources (returned by user navigation initiated RQL queries) can be transformed to HTML and thus displayed by normal web browsers. The portlet is responsible for contacting the RQL interpreter in order to retrieve the corresponding query results (Fig. 5).

In our Portal, two portlets are available for the anonymous user. The left (according to its space arrangement) portlet (Fig. 4a) is responsible for providing a global entry point to the Portal categories regardless of the user's browsing actions. The right portlet provides the information area where the result of user's browsing/querying actions is displayed using the mechanism described previously. The information displayed in this portlet can be either the aggregation of the semantic descriptions of several LOs of a specific type (e.g., all Course Lectures) or the description of a specific LO. Through the proper RDF/S schema relationships we can also navigate among resources without having to necessarily pass through the left portlet. The available left-portlet categories for a specific course are renewed by the left portlet in every user navigation action, thus accounting for any updates. In order to avoid repeating RQL queries to the database, this information is loaded, during portal start-up, into the "main" memory (the shared memory space of the container). In this context, when the views which will be made available for a particular course are changed by an instructor, then to ensure consistency appropriate updates are also performed into the RSSDB Store.

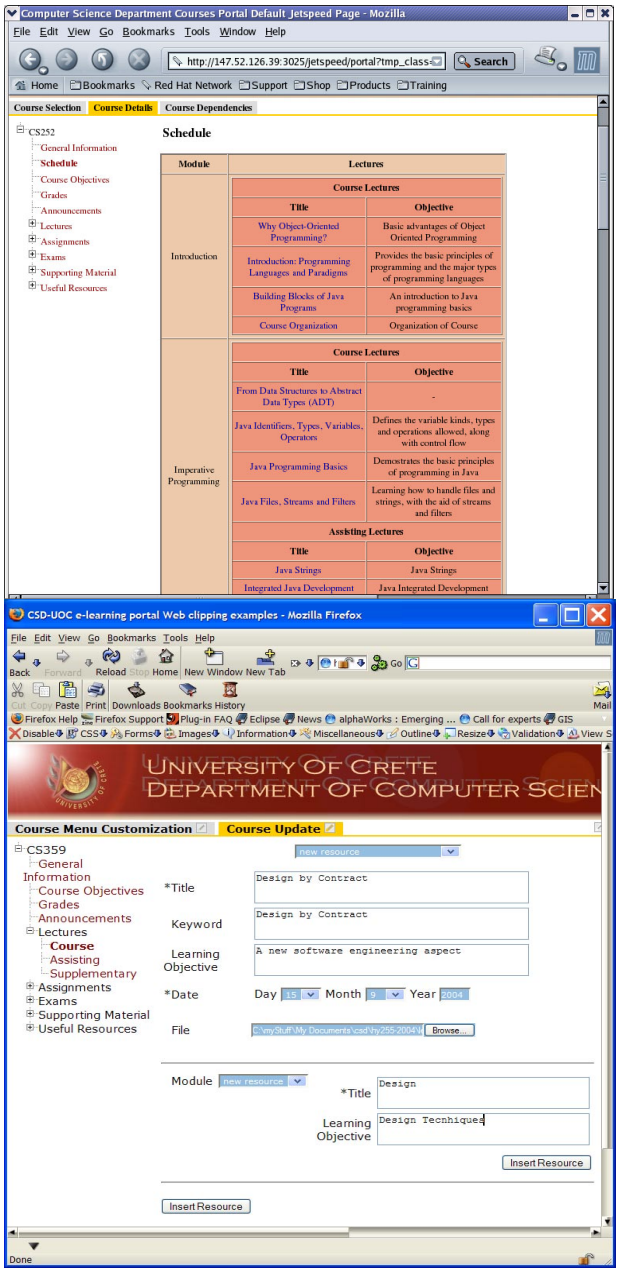

Fig. 4. (a) The initial course page and (b) An update form

4.2 User Authentication

Users have two options when deciding to enter the Online Curriculum Portal. The first is to navigate through the Portal as a common, anonymous user. In this way, they do not need to authenticate themselves but they might be excluded from certain areas of the Portal like the ones containing grading information about the visited course or the ability to post to the course's online forums. Users can alternatively be authenticated using an LDAP-based authentication service hosted by the educational institution and thus acquiring the necessary credentials to fully access or update

the resources of the Portal. Successful authentication enables users to access different portlets than the ones for the anonymous user, i.e., different views of the semantically described LOs and assigns to them a role in the Portal. As mentioned earlier, the available roles are the ones of *administrator*, *instructor* and *learner* along with the *anonymous* user.

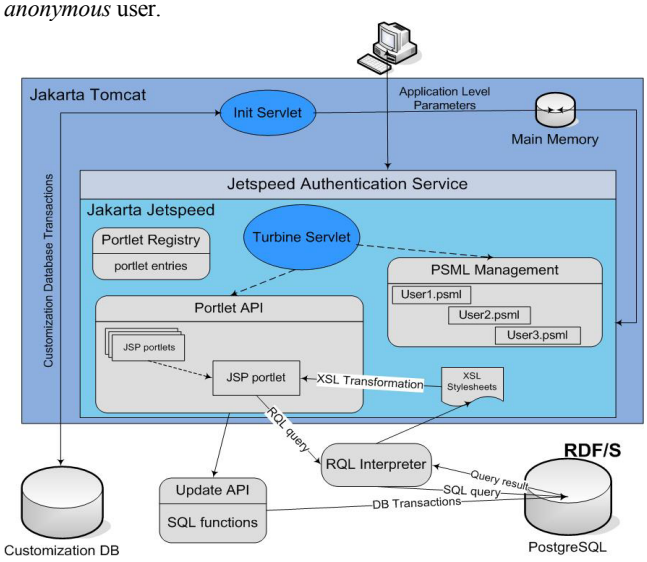

Fig. 5. The CSD-UoC Online Curriculum Portal Architecture

5. RELATED WORK

Online Curriculum Portals aim to support networks of instructors and learners by providing a space of convergence for enhancing peer-to-peer learning interactions among individuals of educational institutions. To this extent, they significantly differ from both commercial and open-source e-learning Portals. Commercial e-learning portal development tools (even high-end ones like Outstarts' TrainerSoft[1], ReadyGo's WebCourseBuilder[2] and Macromedia's CourseBuilder[3]) aim to facilitate users in creating e-learning content while in their majority do not address semantic interoperability issues. Compared to Online Curriculum Portals they mostly use e-learning metadata only a posteriori and, thus, the semantic relationships of LOs are ignored when navigating the e-learning Portals.

On the other hand, strident efforts have taken place to create and maintain LO repositories for various e-learning communities. They can be considered as Learning Content Management Systems (LCMS) and can be divided to either online catalogs of external LOs or digital libraries. The former are holding only the semantic descriptions of LOs stored elsewhere, like the Multimedia Educational Resource for Learning and Online Teaching (MERLOT)[4], the Campus Alberta Repository of Learning Objects (CAREO)[5] and TeleCampus[6]. The latter maintain both internal and external LOs like SMETE[7]. Although they employ standard e-learning metadata specifications to describe the available LOs, they mostly rely on full text queries as the only means to access LOs in a disconnected way from the actual learners' navigation, and thus lacking basic functionality of Online Curriculum Portals.

Learning Management Systems (LMS) and the reference models they implement, like the Shareable Content Object Reference Model[8] (SCORM) and the Open Knowledge Initiative[9] (OKI) share similar motivations with our work. SCORM supports sequencing rules that can be used to specify learning paths of individual LOs rather than semantic relationships of LOs committing to e-learning RDF/S schemas. That way, the association among different LOs takes place only at design/authoring time not allowing for on demand browsing of LOs and thus cannot take advantage of associations established by the learners or other instructors.

Online Curriculum Portals can be also compared to Semantic Web brokerage systems aiming to support large-scale knowledge sharing. For example, ontology-based Portals, like ODESeW [6] (based on WebODE platform), OntoWeb[10] and OntoPortal [5], can also be considered as related to our work although their access and visualization interfaces are too generic to be directly used in e-learning environments[10]. As a matter of fact, many researchers have argued that learning is not the same as knowledge transfer [15]. Moreover, UNIVERSAL[11], is a B2B brokerage platform aiming to support higher education institutions wishing to advertise and exchange their LOs. It provides an RDF/S-based catalog that can be browsed to locate and access LOs of interest. Furthermore, Edutella[12] provides a peer-to-peer infrastructure for connecting peers supporting different types of repositories, query languages, and metadata schemas. Each peer implements a number of basic services such as querying, replication and mapping between different e-learning schemas. Unlike our Portal infrastructure, these systems are lacking personalization facilities for conceptual navigation and retrieval of LOs by declarative queries taking into account the navigation of learners during a session both at the ontology and the resource levels (readers are referred to [2] for a detailed presentation of our Portal GUI and query-based personalization).

Work on adaptive hypermedia can be finally considered as relevant, but most of this work is based upon the generation of learning paths by restricting for instance the available hyperlinks between individual LOs according to an appropriate user model [7, 4]. Systems like Elena (http://www.elena-project.org) extend the Edutella infrastructure for supporting *Smart Learning Spaces* based on dynamic learner profiling using 'personal learning assistants' [13]. A notable effort is the AdaptWeb Project [17] aiming to provide adaptive educational content, personalized according to different courses' and learners' profiles. It relies on LOM to support guided or suggested navigation, hierarchical contents presentation, and sequential deterministic presentations. The AdaptWeb Project mainly focuses on adaptive user profiles, by monitoring users' browsing and retrieval activities inside the Portal. Compared to our approach capturing learners' contextual

[1] http://www.outstart.com/portal/index.jsp

[2] http://www.readygo.com/

[3] http://www.macromedia.com/resources/elearning/extensions/dw_ud/coursebuilder/

[4] http://www.merlot.org/

[5] http://www.careo.org/

[6] http://courses.telecampus.edu

[7] http://www.smete.org/smete/

[8] http://www.adlnet.org/Scorm

[9] http://web.mit.edu/oki

[10] http://www.conzilla.org

[11] http://www.ist-universal.org

[12] http://edutella.jxta.org

access to LOs during a specific navigation session, in the above systems learners' preferences are usually an accumulation of all their past interactions. This is not a suitable approach for Online Curriculum Portals enabling to learn more and new things in different ways from day to day.

6. SUMMARY AND FUTURE WORK

In this paper we have presented the design and implementation using semantic web technologies of an Online Curriculum Portal. Our Portal infrastructure exploits the semantic relationships established among LOs in the context of an educational institution to provide learners with suitable learning paths, as sequences of semantically interrelated LOs that a learner may follow in order to grasp a particular topic. The Portal translates into declarative RQL queries the history of browsing actions learners are performing during a session to provide a contextual access to LOs. XSL transformations are employed to transform the RQL query results to dynamic web pages. Furthermore, our Portal infrastructure relies on a run-time generation of portlets for supporting componentized generation of HTML pages corresponding to instructors or learners' personalized views. An online demo of the CSD-UoC Online Curriculum Portal is available at http://homer.csd.uoc.gr:1025/jetspeed/portal.

We are currently deploying the Portal for widespread use among the instructors and learners of the Computer Science Department of the University of Crete. The evaluation of its use in a real-life environment is crucial in order to validate our current design and implementation choices. Additionally, we are currently integrating our Portal infrastructure with adequate tools facilitating course management tasks like project and assignment submissions, examination scheduling, online tests and forums. The latter will enable users to insert and associate annotations (e.g., questions, comments, etc.) with any available LO under the form of forum posts. One of the future extensions of our Portal is to provide adequate tools facilitating a dynamic and automatic composition of complex LOs. In a first step, we are planning to design ranking algorithms for LO descriptions that take into account users' preferences expressed over the Portal schema and its instance resources. Finally, we would like to enhance the Portal's performances by providing appropriate caching mechanisms for already accessed portlets, as well as, to be able to "export" and publish portlets as web services so that they can be used by other educational institutions without human intervention.

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